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Water-Supply and Irrigation Paper No. 177 Series P, Hydrographic Progress Reports, 53

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

# REPORT

OF

# PROGRESS OF STREAM MEASUREMENTS

FOR

# THE CALENDAR YEAR 1905

PREPARED UNDER THE DIRECTION OF F. H. NEWELL

PART XIII.—Great Basin and Pacific Ocean Drainages in California, and Colorado River Drainage below Gila River

BY

**W. B. CLAPP and J. C. HOYT**

WASHINGTON
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# CONTENTS.


| | Page. |
|---|---|
| Introduction | 1 |
| Organization and scope of work | 1 |
| Definitions | 3 |
| Explanation of tables | 4 |
| Convenient equivalents | 5 |
| Field methods of measuring stream flow | 6 |
| Office methods of computing run-off | 10 |
| Cooperation and acknowledgments | 12 |
| Colorado River drainage basin below Gila River | 13 |
| Colorado River at Yuma, Ariz | 13 |
| Colorado River below heading No. 3 of Imperial canal | 17 |
| Canals below Yuma, Ariz | 18 |
| Colorado Valley Pumping and Irrigation Company's canal at Yuma, Ariz | 18 |
| Farmers' canal near Yuma, Ariz | 19 |
| Ludy canal near Yuma, Ariz | 19 |
| Imperial canal at headings in United States and Mexico | 20 |
| Imperial Valley canals | 25 |
| Lands irrigated in the Imperial Valley | 40 |
| Duty of water in the Imperial Valley | 40 |
| McKim flume | 40 |
| California-Mexico Land and Cattle Company's flume | 41 |
| Miscellaneous measurements | 42 |
| The Great Basin drainage | 42 |
| General features | 42 |
| Susan River drainage basin | 42 |
| Description of basin | 42 |
| Susan River near Susanville, Cal | 42 |
| Willow Creek at Merrillville, Cal | 45 |
| Willow Creek near Standish, Cal | 47 |
| Owens River drainage basin | 49 |
| Description of basin | 49 |
| Owens River near Round Valley, Cal | 50 |
| Rock Creek near Round Valley, Cal | 52 |
| Pine Creek near Round Valley, Cal | 55 |
| Owens River canal near Bishop, Cal | 57 |
| Bishop Creek canal near Bishop, Cal | 58 |
| Farmers' canal near Bishop, Cal | 59 |
| McNally canal near Bishop, Cal | 61 |
| George Collins canal near Bishop, Cal | 61 |
| Bishop Creek near Bishop, Cal | 62 |
| Rawson canal near Bishop, Cal | 65 |
| A. O. Collins canal near Bishop, Cal | 66 |




Digitized by Google

| | Page. |
|---|---|
| The Great Basin drainage—Continued. | |
| Owens River drainage basin—Continued. | |
| Dell canal near Bishop, Cal | 68 |
| Big Pine and Owens River canal near Bishop, Cal | 69 |
| Sanger canal at Alvord, Cal | 70 |
| East Side canal near Citrus, Cal | 71 |
| Stevens canal near Citrus, Cal | 73 |
| Owens River near Citrus, Cal | 74 |
| Powers canal near Bishop, Cal | 76 |
| South Hillside canal near Bishop, Cal | 77 |
| North Hillside canal near Bishop, Cal | 78 |
| Big Pine Creek near Big Pine, Cal | 78 |
| Birch Creek near Tinemaha, Cal | 80 |
| Independence Creek near Independence, Cal | 81 |
| Oak Creek near Independence, Cal | 83 |
| Miscellaneous measurements | 84 |
| Mohave River drainage basin | 87 |
| Description of basin | 87 |
| Mohave River at Victorville, Cal | 87 |
| Southern Pacific Ocean drainage | 91 |
| General features | 91 |
| San Luis Rey River drainage basin | 91 |
| Description of basin | 91 |
| San Luis Rey River near Pala, Cal | 91 |
| Santa Ana River drainage basin | 94 |
| Description of basin | 94 |
| Santa Ana River near Mentone, Cal | 94 |
| Seepage measurements | 99 |
| Miscellaneous measurements | 102 |
| San Gabriel River drainage basin | 104 |
| Description of basin | 104 |
| San Gabriel River and canals near Azusa, Cal | 104 |
| Miscellaneous measurements | 108 |
| Los Angeles River drainage basin | 109 |
| Description of basin | 109 |
| Miscellaneous measurements | 109 |
| Malibu Creek drainage basin | 111 |
| Description of basin | 111 |
| Malibu Creek near Calabasas, Cal | 111 |
| Triunfo Creek near Calabasas, Cal | 113 |
| Santa Clara River drainage basin | 115 |
| Description of basin | 115 |
| Miscellaneous measurements | 115 |
| Santa Ynez River drainage basin | 117 |
| Description of basin | 117 |
| Santa Ynez River near Santa Barbara, Cal | 117 |
| Santa Maria River drainage basin | 120 |
| Description of basin | 120 |
| Santa Maria River near Santa Maria, Cal | 120 |
| Salinas River drainage basin | 123 |
| Description of basin | 123 |
| Arroyo Seco near Soledad, Cal | 123 |
| Miscellaneous measurements in southern California | 126 |


Digitized by Google

Page.
San Francisco Bay drainage basin ..... 127
General features ..... 127
Sacramento River ..... 127
Description of river ..... 127
Sacramento River near Red Bluff, Cal ..... 128
Sacramento River at Sacramento, Cal ..... 131
Miscellaneous measurements ..... 131
Pit River drainage basin ..... 133
Description of basin ..... 133
Pit River near Canby, Cal ..... 134
Pit River near Bieber, Cal ..... 136
South Fork of Pit River near Ivy, Cal ..... 139
West Valley Creek near Likely, Cal ..... 140
Ash Creek at Adin, Cal ..... 144
McCloud River near Gregory, Cal ..... 147
Miscellaneous measurements ..... 151
Stony Creek drainage basin ..... 152
Description of basin ..... 152
Stony Creek near Fruto, Cal ..... 153
Feather River drainage basin ..... 155
Description of basin ..... 155
Feather River at Oroville, Cal ..... 155
Miscellaneous measurements ..... 159
Yuba River drainage basin ..... 159
Description of basin ..... 159
Yuba River near Smartsville, Cal ..... 160
Miscellaneous measurements ..... 164
Bear River drainage basin ..... 165
Description of basin ..... 165
Bear River above Wheatland, Cal ..... 165
Miscellaneous measurements ..... 168
Cache Creek drainage basin ..... 168
Description of basin ..... 168
Clear Lake at Lakeport, Cal ..... 168
Cache Creek at Lower Lake, Cal ..... 169
Cache Creek near Yolo, Cal ..... 172
Miscellaneous measurements ..... 175
American River drainage basin ..... 175
Description of basin ..... 175
American River near Fairoaks, Cal ..... 176
Miscellaneous measurements ..... 178
Puta Creek drainage basin ..... 179
Description of basin ..... 179
Puta Creek near Guenoc, Cal ..... 180
Puta Creek at Winters, Cal ..... 182
San Joaquin River ..... 184
Description of river ..... 184
San Joaquin River at Herndon, Cal ..... 184
Miscellaneous measurements ..... 185
Kern River drainage basin ..... 187
Description of basin ..... 187
Kern River near Bakersfield, Cal ..... 187

Digitized by Google

| | Page. |
|---|---|
| San Francisco Bay drainage basin—Continued. | |
| San Joaquin River—Continued. | |
| Tule River drainage basin | 189 |
| Description of basin | 189 |
| Tule River near Portersville, Cal | 189 |
| Miscellaneous measurements | 191 |
| Kaweah River drainage basin | 192 |
| Description of basin | 192 |
| Kaweah River below Three Rivers, Cal | 192 |
| Miscellaneous measurements | 194 |
| Kings River drainage basin | 195 |
| Description of basin | 195 |
| Kings River near Sanger, Cal | 196 |
| Miscellaneous measurements | 198 |
| Merced River drainage basin | 200 |
| Description of basin | 200 |
| Merced River in Yosemite Valley, Cal | 201 |
| Merced River above Merced Falls, Cal | 203 |
| Yosemite Creek in Yosemite Valley, Cal | 205 |
| Tenaya Creek in Yosemite Valley, Cal | 207 |
| Miscellaneous measurements | 209 |
| Tuolumne River drainage basin | 209 |
| Description of basin | 209 |
| Tuolumne River at Lagrange, Cal | 209 |
| Modesto canal at Lagrange, Cal | 212 |
| Turlock canal at Lagrange, Cal | 214 |
| Miscellaneous measurements | 216 |
| Stanislaus River drainage basin | 217 |
| Description of basin | 217 |
| Stanislaus River at Knights Ferry, Cal | 217 |
| Stanislaus Water Company's ditch at Knights Ferry, Cal | 220 |
| Miscellaneous measurements | 222 |
| Mokelumne River drainage basin | 223 |
| Description of basin | 223 |
| Mokelumne River near Clements, Cal | 223 |
| Northern Pacific Ocean drainage | 225 |
| Russian River drainage basin | 225 |
| Miscellaneous measurements | 225 |
| Eel River drainage basin | 225 |
| Miscellaneous measurements | 225 |
| Klamath River drainage basin | 226 |
| Link River at Klamath Falls, Oreg | 226 |
| Klamath River at Keno, Oreg | 229 |
| Sycan River near Silverlake, Oreg | 232 |
| Lost River near Clear Lake, Cal | 233 |
| Lost River near Merrill, Oreg | 236 |
| Tule Lake near Merrill, Oreg | 238 |
| Miller Creek near Lorella, Oreg | 239 |
| Precipitation and evaporation data | 242 |
| Miscellaneous measurements | 242 |
| Rogue River drainage basin | 249 |
| Rogue River at Gold Ray, Oreg | 249 |


Digitized by Google

Northern Pacific Ocean drainage—Continued. Page.
Umpqua River drainage basin ..... 250
South Fork of Umpqua River near Brockway, Oreg ..... 250
North Fork of Umpqua River near Oakcreek, Oreg ..... 251
Siletz River drainage basin ..... 252
Siletz River at Siletz, Oreg ..... 252
Index ..... 253

# ILLUSTRATIONS.

Page.
PLATE I. Map of the United States, showing location of principal gaging stations maintained during 1905 ..... 2
FIG. 1. Cable station, showing section of river, car, gage, etc ..... 8
2. Discharge, mean-velocity, and area curves for South Fork of Skykomish River near Index, Wash ..... 11

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# PROGRESS REPORT OF STREAM MEASUREMENTS FOR THE CALENDAR YEAR 1905.

## PART XIII.

By W. B. Clapp and J. C. Hoyt.

## INTRODUCTION.

### ORGANIZATION AND SCOPE OF WORK.

The hydrographic work of the United States Geological Survey includes the collection of facts concerning and the study of conditions affecting the behavior of water from the time it reaches the earth as rain or snow until it joins the oceans or great navigable rivers. These investigations became a distinct feature of the work of the Survey in the fall of 1888, when an instruction camp was established at Embudo, N. Mex. The first specific appropriation for gaging streams was made by the act of August 18, 1894, which contained an item of $12,500 "for gauging the streams and determining the water supply of the United States, including the investigation of underground currents and artesian wells in the arid and semi-arid sections." (28 Stat. L., p. 398.)

Since that time the appropriations have been gradually increased, as shown by the following table:

*Annual appropriation for hydrographic surveys, fiscal years ending June 30, 1895 to 1906.*

| | | | |
|---|---|---|---|
| 1895 | $12,500 | 1901 | $100,000 |
| 1896 | 20,000 | 1902 | 100,000 |
| 1897 | 50,000 | 1903 | 200,000 |
| 1898 | 50,000 | 1904 | 200,000 |
| 1899 | 50,000 | 1905 | 200,000 |
| 1900 | 50,000 | 1906 | 200,000 |

As a result of the increased appropriations the work has been greatly extended, and at the same time it has been more thoroughly systematized by the adoption of standard methods and by grouping the States into districts, in each of which a district hydrographer and a corps of assistants carry on a comprehensive study of the hydrographic resources.

The chief features of the hydrographic work are the collection of data relating to the flow of the surface waters and the study of the conditions affecting this flow. Information is also collected concerning river profiles, duration and magnitude of floods, water power, etc., which may be of use in hydrographic studies. This work includes the study of the hydrography of every important river basin in the United States and is of direct value in the commercial and agricultural development of the country.

In order to collect the material from which estimates of daily flow are made, gaging stations are established. The selection of a site for a gaging station and the length of time it is maintained depend largely on the physical features and the needs of each locality. If the water is to be used for power, special effort is made to obtain information concerning



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the minimum flow; if water is to be stored, the maximum flow receives special attention. In all sections of the country permanent gaging stations are maintained for general statistical purposes, to show the conditions existing through long periods. They are also used as primary stations, and their records, in connection with short series of measurements, serve as bases for estimating the flow at other points in the drainage basin.

During the calendar year 1905 the division of hydrography has continued measuring the flow of streams on the same general lines as in previous years. Many new and improved methods have been introduced, by which the accuracy and value of the results have been increased. Approximately 800 regular gaging stations were maintained during the year, and an exceptionally large number of miscellaneous measurements and special investigations were made. The "Report of Progress of Stream Measurements," which contains the results of this work, is published in a series of fourteen Water-Supply and Irrigation Papers, Nos. 165–178, as follows:

No. 165. Atlantic coast of New England drainage.
No. 166. Hudson, Passaic, Raritan, and Delaware river drainages.
No. 167. Susquehanna, Gunpowder, Patapsco, Potomac, James, Roanoke, and Yadkin river drainages.
No. 168. Santee, Savannah, Ogeechee, and Altamaha rivers and eastern Gulf of Mexico drainages.
No. 169. Ohio and lower eastern Mississippi River drainages.
No. 170. Great Lakes and St. Lawrence River drainages.
No. 171. Hudson Bay and upper eastern and western Mississippi River drainages.
No. 172. Missouri River drainage.
No. 173. Meramec, Arkansas, Red, and lower western Mississippi river drainages.
No. 174. Western Gulf of Mexico and Rio Grande drainages.
No. 175. Colorado River drainage.
No. 176. The Great Basin drainage.
No. 177. The Great Basin and Pacific Ocean drainages in California.
No. 178. Columbia River and Puget Sound drainages.

These papers embody the data collected at the regular gaging stations, the results of the computations based on the observations, and such other information as may have a direct bearing on the study of the subject, and include, as far as practicable, descriptions of the basins and the streams draining them.

For the purpose of introducing uniformity into the reports for the various years the drainages of the United States have been divided into eleven grand divisions, which have been again divided into secondary divisions, as shown in the following list. The Progress Report has been made to conform to this arrangement, each part containing the data for one or more of the secondary divisions. The secondary divisions have in most cases been redivided, and the facts have been arranged, as far as practicable, geographically.

*List of drainage basins in the United States.*

NORTHERN ATLANTIC DRAINAGE BASINS.

St. John.
St. Croix.
Penobscot.
Kennebec.
Androscoggin.
Presumpscot.
Saco.
Merrimac.
Connecticut.
Blackstone.
Thames.
Housatonic.
Hudson.
Passaic.
Raritan.
Delaware.
Susquehanna.
Potomac.
Minor Chesapeake Bay.
Minor Northern Atlantic.

SOUTHERN ATLANTIC DRAINAGE BASINS.

James.
Chowan.
Roanoke.
Tar.
Neuse.
Cape Fear.
Great Pedee (Yadkin).
Santee.
Savannah.
Ogeechee.
Altamaha.
Minor Southern Atlantic.

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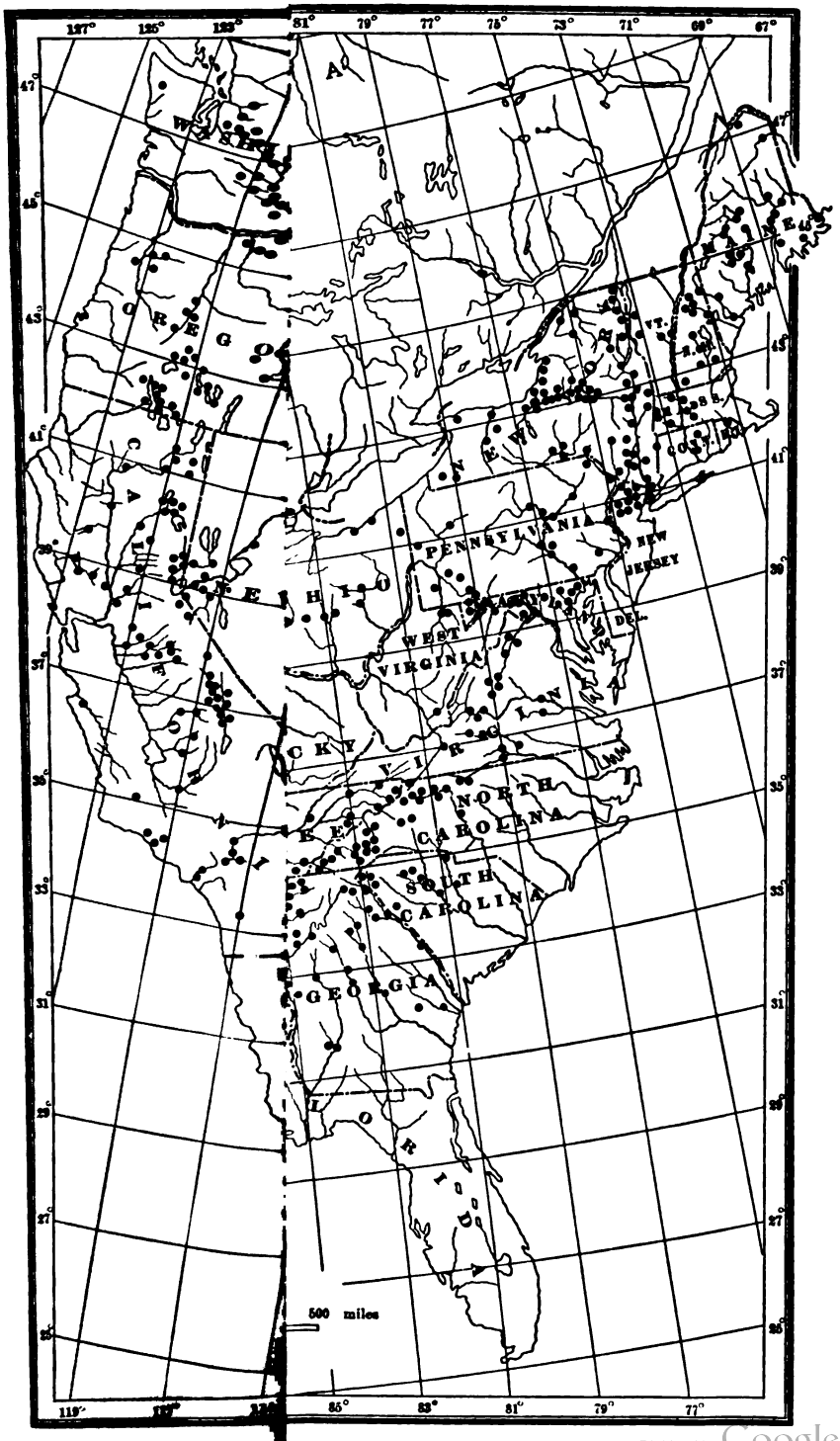


DURING 1905.

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EASTERN GULF OF MEXICO DRAINAGE BASINS.

Suwanee.
Apalachicola.
Mobile.
Pearl.
Minor Eastern Gulf of Mexico.

EASTERN MISSISSIPPI RIVER DRAINAGE BASINS.

Lower eastern Mississippi.
Ohio.
Upper eastern Mississippi.

ST. LAWRENCE RIVER DRAINAGE BASINS.

Lake Superior.
Lake Michigan.
Lake Huron.
Lake St. Clair.
Lake Erie.
Niagara River.
Lake Ontario.
Lake Champlain (Richelieu River).
Minor St. Lawrence.

WESTERN MISSISSIPPI RIVER DRAINAGE BASINS.

Upper western Mississippi.
Missouri.
Meramec.
Lower western Mississippi.
Arkansas.
Red.

WESTERN GULF OF MEXICO DRAINAGE BASINS.

Sabine.
Neches.
Trinity.
Brazos.
Colorado (of Texas).
Guadalupe.
San Antonio.
Nueces.
Rio Grande.
Minor Western Gulf of Mexico.

COLORADO RIVER DRAINAGE BASIN.

THE GREAT BASIN.

Wasatch Mountains.
Humboldt.
Sierra Nevada.
Minor streams in Great Basin.

PACIFIC COAST DRAINAGE BASINS.

Southern Pacific.
San Francisco Bay.
Northern Pacific.
Columbia.
Puget Sound.

HUDSON BAY DRAINAGE BASINS.

## DEFINITIONS.

The volume of water flowing in a stream, the "run-off" or "discharges," is expressed in various terms, each of which has become associated with a certain class of work. These terms may be divided into two groups—(1) those which represent a rate of flow, as second-feet, gallons per minute, miner's inch, and run-off in second-feet per square mile; and (2) those which represent the actual quantity of water, as run-off in depth in inches and acre-feet. They may be defined as follows:

"Second-foot" is an abbreviation for cubic foot per second, and is the quantity of water flowing in a stream 1 foot wide, 1 foot deep, at a rate of 1 foot per second. It is generally used as a fundamental unit from which others are computed.

"Gallons per minute" is generally used in connection with pumping and city water supply.

The "miner's inch" is the quantity of water that passes through an orifice 1 inch square under a head which varies locally. It has been commonly used by miners and irrigators throughout the West, and is defined by statute in each State in which it is used. In most States the California miner's inch is used, which is the fiftieth part of a second-foot.

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"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly, both as regards time and area.

"Run-off in inches" is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is usually expressed in depth in inches.

"Acre-foot" is equivalent to 43,560 cubic feet, and is the quantity required to cover an acre to the depth of 1 foot. It is commonly used in connection with storage for irrigation work. There is a convenient relation between the second-foot and the acre-foot. One second-foot flowing for twenty-four hours will deliver 86,400 cubic feet, or approximately 2 acre-feet.

## EXPLANATION OF TABLES.

For each regular gaging station are given, as far as available, the following data:

1. Description of station.
2. List of discharge measurements.
3. Gage-height table.
4. Rating table.
5. Table of estimated monthly and yearly discharges and run-off, based on all the facts obtained to date.

The descriptions of stations give such general information about the locality and equipment as would enable the reader to find and use the station. They also give, as far as possible, a complete history of all the changes since the establishment of the station that would be factors in using the data collected.

The discharge-measurement table gives the results of the discharge measurements made during the year, including the date, the name of the hydrographer, the area of cross section, the mean velocity, the gage height, and the discharge in second-feet.

The table of daily gage heights gives the daily fluctuations of the surface of the river as found from the mean of the gage readings taken each day. The gage height given in the table represents the elevation of the surface of the water above the zero of the gage. At most stations the gage is read in the morning and in the evening.

The rating table gives discharges in second-feet corresponding to each stage of the river as given by the gage heights.

In the table of estimated monthly discharge, the column headed "Maximum" gives the mean flow for the day when the mean gage height was highest, and it is the flow as given in the rating table for that mean gage height. As the gage height is the mean for the day, there might have been short periods when the water was higher and the corresponding discharge larger than given in this column. Likewise in the column of "Minimum" the quantity given is the mean flow for the day when the mean gage height was lowest. The column headed "Mean" is the average flow for each second during the month. On this are based the computations for the three remaining columns, which are defined above.

In the computations for the tables of this report the following general and special rules have been used:

*Fundamental rules for computation.*

1. The highest degree of precision consistent with the rational use of time and money is imperative.
2. All items of computation should be expressed by at least two and not more than four significant figures.
3. Any measurement in a vertical velocity, mean velocity, or discharge curve whose per cent of error is five times the average per cent of error of all the other measurements should be rejected.
4. In reducing the number of significant figures, or the number of decimal places, by dropping the last figure, the following rules apply:

(*a*) When the figure in the place to be rejected is less than 5, drop it without changing the preceding figure. Example: 1,827.4 becomes 1,827.

(*b*) When the figure in the place to be rejected is greater than 5, drop it and increase the preceding figure by 1. Example: 1,827.6 becomes 1,828.

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(*c*) When the figure in the place to be rejected is 5 and it is preceded by an even figure, drop the 5. Example: 1,828.5 becomes 1,828.

(*d*) When the figure in the place to be rejected is 5 and it is preceded by an odd figure, drop the 5 and increase the preceding figure by 1. Example: 1,827.5 becomes 1,828.

*Special rules for computation.*

1. Rating tables are to be constructed as closely as the data on which they are based will warrant. No decimals are to be used when the discharge is over 50 second-feet.

2. Daily discharges shall be applied directly to the gage heights as they are tabulated.

3. Monthly means are to be carried out to one decimal place when the quantities are below 100 second-feet. Between 100 and 10,000 second-feet, the last figure in the monthly mean shall be a significant figure. This also applies to the yearly mean.

4. Second-feet per square mile and depth in inches for the individual months shall be carried out to at least three significant figures, except in the case of decimals where the first significant figure is preceded by one or more naughts (0), when the quantity shall be carried out to two significant figures. Example: 1.25; .125; .012; .0012. The yearly means for these quantities are always to be expressed in three significant figures and at least two decimal places.

## CONVENIENT EQUIVALENTS.

1 second-foot equals 50 California miner's inches.
1 second-foot equals 38.4 Colorado miner's inches.
1 second-foot equals 40 Arizona miner's inches.
1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646,272 gallons for one day.
1 second-foot equals 6.23 British imperial gallons per second.
1 second-foot for one year covers 1 square mile 1.131 feet deep, 13.572 inches deep.
1 second-foot for one year equals 0.000214 cubic mile; equals 31,536,000 cubic feet.
1 second-foot equals about 1 acre-inch per hour.
1 second-foot falling 10 feet equals 1.136 horsepower.
100 California miner's inches equal 15 United States gallons per second.
100 California miner's inches equal 77 Colorado miner's inches.
100 California miner's inches for one day equal 4 acre-feet.
100 Colorado miner's inches equal 2.60 second-feet.
100 Colorado miner's inches equal 19.5 United States gallons per second.
100 Colorado miner's inches equal 130 California miner's inches.
100 Colorado miner's inches for one day equal 5.2 acre-feet.
100 United States gallons per minute equal 0.223 second-foot.
100 United States gallons per minute for one day equal 0.44 acre-foot.
1,000,000 United States gallons per day equal 1.55 second-feet.
1,000,000 United States gallons equal 3.07 acre-feet.
1,000,000 cubic feet equal 22.95 acre-feet.
1 acre-foot equals 325,850 gallons.
1 inch deep on 1 square mile equals 2,323,200 cubic feet.
1 inch deep on 1 square mile equals 0.0737 second-foot per year.
1 inch equals 2.54 centimeters.
1 foot equals 0 3048 meter.
1 yard equals 0.9144 meter.
1 mile equals 1.60935 kilometers.
1 mile equals 1,760 yards; equals 5,280 feet; equals 63,360 inches.
1 square yard equals 0.836 meter.
1 acre equals 0.4047 hectare.
1 acre equals 43,560 square feet; equals 4,840 square yards.
1 acre equals 209 feet square, nearly.
1 square mile equals 259 hectares.
1 square mile equals 2.59 square kilometers.
1 cubic foot equals 0.0283 cubic meter.
1 cubic foot equals 7.48 gallons; equals 0.804 bushel.
1 cubic foot of water weighs 62.5 pounds.
1 cubic yard equals 0.7646 cubic meter.
1 cubic mile equals 147,198,000,000 cubic feet.
1 cubic mile equals 4,667 second-feet for one year.
1 gallon equals 3.7854 liters.
1 gallon equals 8.36 pounds of water.
1 gallon equals 231 cubic inches (liquid measure).
1 pound equals 0.4536 kilogram.
1 avoirdupois pound equals 7,000 grains.

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1 troy pound equals 5,760 grams.
1 meter equals 39.37 inches. Log. 1.5951654.
1 meter equals 3.280833 feet. Log. 0.5159842.
1 meter equals 1.093611 yards. Log. 0.0388629.
1 kilometer equals 3,281 feet; equals five-eighths mile, nearly.
1 square meter equals 10,764 square feet; equals 1,196 square yards.
1 hectare equals 2.471 acres.
1 cubic meter equals 35.314 cubic feet; equals 1.308 cubic yards.
1 liter equals 1.0567 quarts.
1 gram equals 15.43 grains.
1 kilogram equals 2.2046 pounds.
1 tonneau equals 2,204.6 pounds.
1 foot per second equals 1.097 kilometers per hour.
1 foot per second equals 0.68 mile per hour.
1 cubic meter per minute equals 0.5886 second-foot.
1 atmosphere equals 15 pounds per square inch; equals 1 ton per square foot; equals 1 kilogram per square centimeter.
Acceleration of gravity equals 32.16 feet per second every second.
1 horsepower equals 550 foot-pounds per second.
1 horsepower equals 76 kilogram-meters per second.
1 horsepower equals 746 watts.
1 horsepower equals 1 second-foot falling 8.8 feet.
1½ horsepowers equal about 1 kilowatt.

To calculate water power quickly: $\frac{\text{Sec.-ft.} \times \text{fall in feet}}{11}$ = Net horsepower on water wheel, realizing 80 per cent of the theoretical power.

Quick formula for computing discharge over weirs: Cubic feet per minute equals $0.4025\, l\sqrt{h^3}$; $l$=length of weir in inches; $h$=head in inches flowing over weir, measured from surface of still water.

To change miles to inches on map:

Scale 1 : 125000, 1 mile=0.50688 inch.
Scale 1 : 90000, 1 mile=0.70400 inch.
Scale 1 : 62500, 1 mile=1.01376 inches.
Scale 1 : 45000, 1 mile=1.40800 inches.

## FIELD METHODS OF MEASURING STREAM FLOW.

The methods used in collecting these data and in preparing them for publication are given in detail in Water-Supply Papers No. 94 (Hydrographic Manual, U. S. Geol. Survey) and No. 95 (Accuracy of Stream Measurements). In order that those who use this report may readily become acquainted with the general methods employed, the following brief description is given:

Streams may be divided, with respect to their physical conditions, into three classes—(1) those with permanent beds; (2) those with beds which change only during extreme low or high water; (3) those with constantly shifting beds. In estimating the daily flow special methods are necessary for each class. The data on which these estimates are based and the methods of collecting them are, however, in general the same.

There are three distinct methods of determining the flow of open-channel streams—(1) by measurements of slope and cross section and the use of Chezy's and Kutter's formulas; (2) by means of a weir; (3) by measurements of the velocity of the current and of the area of the cross section. The method chosen for any case depends on the local physical conditions, the degree of accuracy desired, the funds available, and the length of time that the record is to be continued.

*Slope method.*—Much information has been collected relative to the coefficients to be used in the Chezy formula, $v=c\sqrt{R\,s}$. This has been utilized by Kutter, both in developing his formula for $c$ and in determining the values of the coefficient $n$ which appears therein. The results obtained by the slope method are in general only roughly approximate, owing to the difficulty in obtaining accurate data and the uncertainty of the value for $n$ to be used in Kutter's formula. The most common use of this method is in estimating the flood discharge of a stream when the only data available are the cross section, the slope as shown by marks along the bank, and a knowledge of the general conditions.

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*Weir method.*—When funds are available and the conditions are such that sharp-crested weirs can be erected, these offer the best facilities for determining flow. If dams are suitably situated and constructed, they may be utilized for obtaining reliable estimates of flow. The conditions necessary to insure good results may be divided into two classes—(1) those relating to the physical characteristics of the dam itself, and (2) those relating to the diversion and use of water around and through the dam.

The physical requirements are as follows: (*a*) Sufficient height of dam, so that backwater will not interfere with free fall over it; (*b*) absence of leaks of appreciable magnitude; (*c*) topography or abutments which confine the flow over the dam at high stages; (*d*) level crests, which are kept free from obstructions caused by floating logs or ice; (*e*) crests of a type for which the coefficients to be used in $Q=cbh^{\frac{3}{2}}$, or some similar standard weir formula, are known (see Water-Supply Paper No. 150); (*f*) either no flash-boards or exceptional care in reducing leaking through them and in recording their condition.

Preferably there should be no diversion of water through or around the dam. Generally, however, the dam is built for purposes of power or navigation, and part or all of the water flowing past it is diverted for such uses. This water is measured and added to that passing over the dam. To insure accuracy in such estimates the amount of water diverted should be reasonably constant. Furthermore, it should be so diverted that it can be measured, either by a weir, a current meter, or a simple system of water wheels which are of standard make, or which have been rated as meters under working conditions and so installed that the gate openings the heads under which they work, and their angular velocities may be accurately observed.

The combination of physical conditions and uses of the water should be such that the estimates of flow will not involve, for a critical stage of considerable duration, the use of a head on a broad-crested dam, of less than 6 inches. Moreover, when all other conditions are good, the cooperation of the owners or operators of the plant is still essential if reliable results are to be obtained.

A gaging station at a weir or dam has the general advantage of continuity of record through the periods of ice and floods, and the disadvantages of uncertainty of coefficient be used in the weir formula, and of complications in the diversion and use of the water.

*Velocity method.*—The determination of the quantity of water flowing past a certain section of a stream at a given time is termed a discharge measurement. This quantity is the product of two factors—the mean velocity and the area of the cross section. The mean velocity is a function of surface slope, wetted perimeter, roughness of bed, and the channel conditions at, above, and below the gaging section. The area depends on the contour of the bed and the fluctuations of the surface. The two principal ways of measuring the velocity of a stream are by floats and current meters.

Great care is taken in the selection and equipment of gaging stations for determining discharge by velocity measurements in order that the data may have the required degree of accuracy. Their essential requirements are practicaliy the same whether the velocity is determined by meters or floats. They are located as far as possible where the channel is straight both above and below the gaging section; where there are no cross currents, backwater, or boils; where the bed of the stream is reasonably free from large projections of a permanent character; and where the banks are high and subject to overflow only at flood stages. The station must be so far removed from the effects of tributary streams and dams or other artificial obstructions that the gage height shall be an index of the discharge.

Certain permanent or semi-permanent structures, usually referred to as "equipment," are generally pertinent to a gaging station. These are a gage for determining the fluctuations of the water surface, bench marks to which the datum of the gage is referred, permanent marks on a bridge or a tagged line indicating the points of measurement, and where the current is swift, some appliance (generally a secondary cable) to hold the meter in position in the water. As a rule, the stations are located at bridges if the channel conditions are satisfactory, as from them the observations can more readily be made and the cost of the equipment is small.

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The floats in common use are the surface, subsurface, and tube or rod floats. A corked bottle with a flag in the top and weighted at the bottom makes one of the most satisfactory surface floats, as it is affected but little by wind. In case of flood measurements, good results can be obtained by observing the velocity of floating cakes of ice or débris. In case of all surface-float measurements coefficients must be used to reduce the observed velocity to the mean velocity. The subsurface and tube or rod floats are intended to give directly the mean velocity in the vertical. Tubes give excellent results when the channel conditions are good, as in canals.

In measuring velocity by a float, observation it made of the time taken by the float to pass over the "run," a selected stretch of river from 50 to 200 feet long. In each discharge measurement a large number of velocity determinations are made at different points across the stream, and from these observations the mean velocity for the whole section is determined. This may be done by plotting the mean positions of the floats as indicated by the distances from the bank as ordinates, and the corresponding times as abscissas. A curve through these points shows the mean time of run at any point across the stream, and the mean time for the whole stream is obtained by dividing the area bounded by this curve and its axis by the width. The length of the run divided by the mean time gives the mean velocity.

The area used in float measurements is the mean of the areas at the two ends of the run and at several intermediate sections.

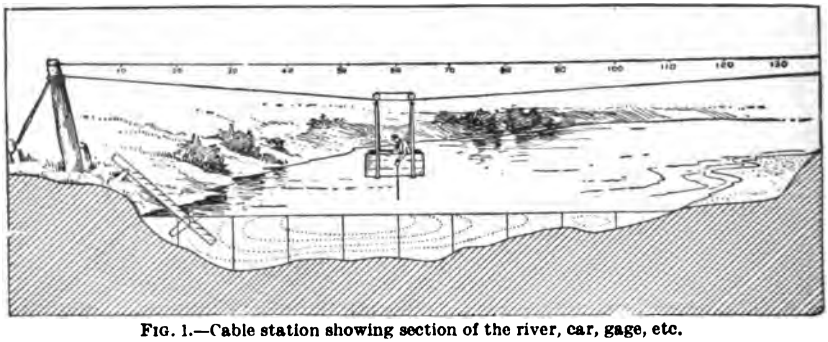

FIG. 1.—Cable station showing section of the river, car, gage, etc.

The essential parts of the current meters in use are a wheel of some type, so constructed that the impact of flowing water causes it to revolve, and a device for recording or indicating the number of revolutions. The relation between the velocity of the moving water and the revolutions of the wheel is determined for each meter. This rating is done by drawing the meter through still water for a given distance at different speeds, and noting the number of revolutions for each run. From these data a rating table is prepared which gives the velocity per second for any number of revolutions.

Many kinds of current meters have been constructed. They may, however, be classed in two general types—those in which the wheel is made up of a series of cups, as the Price, and those having a screw-propeller wheel, as the Haskell. Each meter has been developed for use under some special condition. In the case of the small Price meter, which has been largely developed and extensively used by the United States Geological Survey, an attempt has been made to get an instrument which could be used under practically all conditions.

Current-meter measurements may be made from a bridge, cable, boat, or by wading, and gaging stations may be classified in accordance with such use. Fig. 1 shows a typical cable station.

In making the measurement an arbitrary number of points are laid off on a line perpendicular to the thread of the stream. The points at which the velocity and depth are observed are known as measuring points and are usually fixed at regular intervals, varying from 2 to 20 feet, depending on the size and conditions of the stream. Perpendiculars

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dropped from the measuring points divide the gaging section into strips. For each strip or pair of strips the mean velocity, area, and discharge are determined independently, so that conditions existing in one part of the stream may not be extended to parts where they do not apply.

Three classes of methods of measuring velocity with current meters are in general use—multiple point, single point, and integration.

The three principal multiple-point methods in general use are the vertical velocity-curve; 0.2 and 0.8 depth; and top, bottom, and mid-depth.

In the vertical velocity-curve method a series of velocity determinations are made in each vertical at regular intervals, usually from 0.5 to 1 foot apart. By plotting these velocities as abscissas and their depths as ordinates, and drawing a smooth curve among the resulting points, the vertical velocity-curve is developed. This curve shows graphically the magnitude and changes in velocity from the surface to the bottom of the stream. The mean velocity in the vertical is then obtained by dividing the area bounded by this velocity-curve and its axis by the depth. On account of the length of time required to make a complete measurement by this method, its use is limited to the determination of coefficients for purposes of comparison, and to measurements under ice.

In the second multiple-point method the meter is held successively at 0.2 and 0.8 of the depth, and the mean of the velocities at these two points is taken as the mean velocity for that vertical. Assuming that the vertical velocity-curve is a common parabola with horizontal axis, the mean of the velocities at 0.22 and 0.79 of the depth will give (closely) the mean velocity in the vertical. Actual observations under a wide range of conditions show that this second multiple-point method gives the mean velocity very closely for open-water conditions where the depth is over 5 feet and the bed comparatively smooth, and moreover the indications are that it will hold nearly as well for ice-covered rivers.

In the third multiple-point method the meter is held at mid-depth, at 0.5 foot below the surface, and at 0.5 foot above the bottom, and the mean velocity is determined by dividing by 6 the sum of the top velocity, four times the mid-depth velocity, and the bottom velocity. This method may be modified by observing at 0.2, 0.6, and 0.8 depth.

The single-point method consists in holding the meter either at the depth of the thread of mean velocity, or at an arbitrary depth for which the coefficient for reducing to mean velocity has been determined.

Extensive experiments by vertical velocity-curves show that the thread of mean velocity generally occurs at from 0.5 to 0.7 of the total depth. In general practice the thread of mean velocity is considered to be at 0.6 depth, at which point the meter is held in a majority of the measurements. A large number of vertical velocity-curve measurements taken on many streams and under varying conditions show that the average coefficient for reducing the velocity obtained at 0.6 depth to mean velocity is practically unity.

In the other principal single-point method the meter is held near the surface, usually 1 foot below, or low enough to be out of the effect of the wind or other disturbing influences. This is known as the subsurface method. The coefficient for reducing the velocity taken at the subsurface to the mean has been found to be from 0.85 to 0.95, depending on the stage, velocity, and channel conditions. The higher the stage the larger the coefficient. This method is specially adapted for flood measurements or when the velocity is so great that the meter can not be kept at 0.6 depth.

The vertical-integration method consists in moving the meter at a slow uniform speed from the surface to the bottom and back again to the surface, and noting the number of revolutions and the time taken in the operation. This method has the advantage that the velocity at each point of the vertical is measured twice. It is well adapted for measurements under ice and as a check on the point methods.

The area, which is the other factor in the velocity method of determining the discharge of a stream, depends on the stage of the river, which is observed on the gage, and on the general contour of the bed of the stream, which is determined by soundings. The soundings are usually taken at each measuring point at the time of the discharge measurement, either



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by using the meter and cable, or by a special sounding line or rod. For streams with permanent beds standard cross sections are usually taken during low water. These sections serve to check the soundings which are taken at the time of the measurements, and from them any change which may have taken place in the bed of the stream can be detected. They are also of value in obtaining the area for use in computations of high-water measurements, as accurate soundings are hard to obtain at high stages.

In computing the discharge measurements from the observed velocities and depths at various points of measurement, the measuring section is divided into elementary strips, as shown in fig. 1, and the mean velocity, area, and discharge are determined separately for either a single or a double strip. The total discharge and the area are the sums of those for the various strips, and the mean velocity is obtained by dividing the total discharge by the total area.

The determination of the flow of an ice-covered stream is difficult, owing to diversity and instability of conditions during the winter period, and also to lack of definite information in regard to the laws of flow of water under ice. The method now employed is to make freqeunt discharge measurements during the frozen periods by the vertical velocity-curve method, and to keep an accurate record of the conditions, such as the gage height to the surface of the water as it rises in a hole cut in the ice, the thickness and character of the ice, etc. From these data an approximate estimate of the daily flow can be made by constructing a rating curve (really a series of curves) similar to that used for open channels, but considering in addition to gage heights and discharge, the varying thickness of ice. Such data as are available in regard to this subject are published in Water-Supply Paper No. 146, pages 141–148.

## OFFICE METHODS OF COMPUTING RUN-OFF.

There are two principal methods of estimating run-off, depending on whether or not the bed of the stream is permanent.

For stations on streams with permanent beds the first step in computing the run-off is the construction of a rating table, which shows the discharge corresponding to any stage of the stream. This rating table is applied to the record of stage to determine the amount of water flowing. The construction of the rating table depends on the method used in measuring flow.

For a station at a weir or dam, the basis for the rating table is some standard weir formula. The coefficients to be used in its application depend on the type of dam and other conditions near its crest. After inserting in the weir formula the measured length of crest and the assumed coefficient, the discharge is computed for various heads and the rating table constructed.

The data necessary for the construction of a rating table for a velocity-area station are the results of the discharge measurements, which include the record of stage of the river at the time of measurement, the area of the cross section, the mean velocity of the current, and the quantity of water flowing. A thorough knowledge of the conditions at and in the vicinity of the station is also necessary.

The construction of the rating table depends on the following laws of flow for open permanent channels: (1) The discharge will remain constant so long as conditions at or near the gaging station remain constant. (2) The discharge will be the same whenever the stream is at a given stage if the change of slope due to the rise and fall of the stream be neglected. (3) The discharge is a function of and increases gradually with the stage.

The plotting of results of the various discharge measurements, using gage heights as ordinates; and discharge, mean velocity, and area as abscissas will define curves which show the discharge, mean velocity, and area corresponding to any gage height. For the development of these curves there should be, therefore, a sufficient number of discharge measurements to cover the range of the stage of the stream. Fig. 2 shows a typical rating curve with its corresponding mean-velocity and area curves.

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As the discharge is the product of two factors, the area and the mean velocity, any change in either factor will produce a corresponding change in the discharge. Their curves are therefore constructed in order to study each independently of the other.

The area curve can be definitely determined from accurate soundings extending to the limits of high water. It is always concave toward the hortzontal axis or on a straight line, unless the banks of the stream are overhanging.

The form of the mean-velocity curve depends chiefly on the surface slope, the roughness of the bed, and the cross section of the stream. Of these, the slope is the principal factor. In accordance with the relative changes of these factors the curve may be either a straight line, convex, or concave toward either axis, or a combination of the three. From a careful study of the conditions at any gaging station the form which the vertical velocity-curve will take can be predicted, and it may be extended with reasonable certainty to stages beyond the limits of actual measurements. Its principal use is in connection with the area curve in locating errors in discharge measurements and in constructing the rating table.

The discharge curve is defined primarily by the measurements of discharge, which are studied and weighted in accordance with the local conditions existing at the time of each

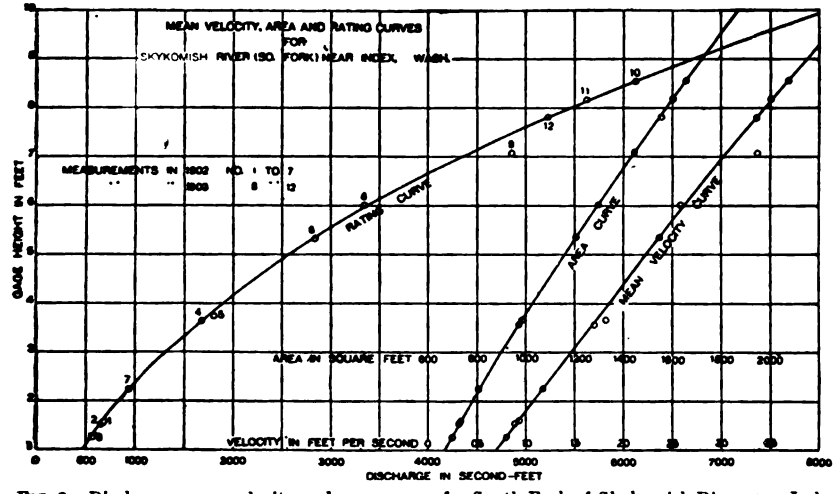


FIG. 2.—Discharge mean-velocity and area curves for South Fork of Skykomish River near Index.

measurement. The curve may, however, best be located between and beyond the measurements by means of curves of area and mean velocity. The discharge curve under normal conditions is concave toward the horizontal axis and is generally parabolic in form.

In the preparation of the rating table the discharge for each tenth or half tenth on the gage is taken from the curve. The differences between successive discharges are then taken and adjusted according to the law that they shall be either constant or increasing.

The determination of daily discharge of streams with changeable beds is a difficult problem In case there is a weir or dam available, a condition which seldom exists on streams of this class, estimates can be obtained by its use. In case of velocity-area stations frequent discharge measurements must be made if the estimates are to be other than rough approximations. For stations with beds which shift slowly, or are materially changed only during floods, rating tables can be prepared for periods between such changes and satisfactory results obtained with a limited number of measurements, provided that some of them are taken soon after the change occurs. For streams with continually shifting beds, such as the Colorado and Rio Grande, discharge measurements should be made every two or three days and the discharges for intervening days obtained either by interpolation modified by

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gage height or by Professor Stout's method, which has been described in full in the Nineteenth Annual Report of the United States Geological Survey, Part IV, page 323, and in the Engineering News of April 21, 1904. This method, or a graphical application of it, is also much used in estimating flow at stations where the bed shifts but slowly.

## COOPERATION AND ACKNOWLEDGMENTS.

Most of the measurements presented in this paper have been obtained through local hydrographers. Acknowledgment is due to each of these persons, and thanks are extended to other persons and corporations who have assisted local hydrographers or have cooperated in any way, either by furnishing records of the height of water or by assisting in transportation.

The hydrographic work of the United States Geological Survey in California is being carried on in cooperation with the State, in accordance with acts of the State legislature approved March 16, 1903, and March 20, 1905.

The act of March 16, 1903, which covered the period from July 1, 1903, to June 30, 1905, is in substance as follows:

> The State board of examiners are hereby empowered to enter into contracts with the Director of the United States Geological Survey for the purpose of making topographic maps to the extent of twenty thousand dollars; also for the purpose of gaging streams, surveying reservoir sites and canal locations, for the conservation and utilization of the flood or storm waters of the State, to the extent of fifteen thousand dollars, [etc.]

The act of March 20, 1905, is in substance the same as previous act, the appropriations being increased to $30,000 for topography and $20,000 for hydrography, and covering the two fiscal years July 1, 1905, to June 30, 1907.

The State board of examiners is composed of the following members: George C. Pardee, governor; C. F. Curry, secretary of state; U. S. Webb, attorney-general.

Although the portions of these bills referring to hydrographic work provide for making surveys of reservoir sites and canal locations, none of the State money has been expended for this purpose. The Geological Survey has made these investigations on Puta Creek, Cache Creek, Sacramento River, Pit River and tributaries, Feather River and tributaries, Owens River, and Colorado River, and has paid the entire expense from its own funds.

The State appropriation of $15,000, which was available between July 1, 1903, and June 30, 1905, was used exclusively for gathering general stream-flow data. The Survey also apportioned $20,000 for the same purpose during the same period. The data being accumulated have a specific value in connection with the future development of the resources of the State. The information will be invaluable in designing and making estimates of cost for storage, irrigation, power and drainage works, and for use in litigation.

The work in California is under the direction of Supervising Engineer J. B. Lippincott,[a] assisted by Engineer W. B. Clapp, who has immediate charge of the accumulation of hydrographic data. Acknowledgments are also due to the following individuals and corporations for assistance rendered and data furnished: To J. C. Pierson, city surveyor of Sacramento, Cal., for river-stage and turbidity records of Sacramento River at Sacramento; to the Kern County Land Company, through A. K. Warren, engineer in charge of water measurements, for the record of Kern River; to the city of Santa Barbara for cooperation in gaging Santa Ynez River; to the Bay Cities Water Company, through Edwin Duryea, jr., chief engineer, for precipitation and run-off data; to the Southern Pacific Company, through its chief engineer, William Hood, for river-stage records of San Joaquin River at Herndon, Cal., and for transportation furnished the supervising engineer and assistants; and to the officials of the Santa Fe Railway for transportation furnished to the supervising engineer and assistants.

The work in the extreme eastern portion of California was carried on under the direction of Henry Thurtell,[b] State engineer of Nevada, assisted by W. A. Wolf, J. T. Shaw, R. A. Craig, O. F. Heizer, and L. A. Wooley. Acknowledgment is due to the Southern Pacific Company for transportation furnished the district hydrographers and assistants.

[a] Office, 1108 Union Trust Building, Los Angeles, Cal. [b] Office, Carson, Nev.

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## COLORADO RIVER DRAINAGE BASIN BELOW GILA RIVER.

### COLORADO RIVER AT YUMA, ARIZ.

This station is located in the town of Yuma, Ariz., 1½ miles below the mouth of Gila River and 10 miles, by river, above the Mexican boundary. Records of river height have been kept by the Southern Pacific Company since April 1, 1878, on the gage which was established by Arthur Brown, superintendent of the company's bridge and building department, during the summer of 1876.

The channel of the main river is straight for 600 feet above and 5,000 feet below the station. The right bank is low, wooded, and liable to overflow; the left bank is not subject to overflow. The bed of the stream is composed of silt and sand and is very unstable. At low water the channel has a width of 300 feet; at flood stages a large part of the water flows through an old channel and does not pass under the cable. The current is swift and the gaging section regular. At all stages of the river the depth and the velocity are uniform and there are no large eddies.

Prior to May 31, 1903, discharge measurements were made from the railroad bridge. On that date a cable station was established at a point 600 feet below the bridge, and all measurements are now made from a car, except during highest floods, when a boat is used. The cable is supported on masts and is equipped with a winch, by which it can be lowered for the passage of boats. The cable has a span of 650 feet. The initial point for soundings is the cable support on the south or left bank about 20 feet from the water's edge at high water. The water that flows in the old channel at flood stages is measured at the point where it passes under the railway trestle, one-third mile north of the main channel. During the flood of May and June, 1905, there were two breaks in the railroad grade at Araz, Cal., 4 miles from Yuma, and the water passing through these is included in each discharge measurement of the Colorado.

The gage, which was read twice each day during 1905 by W. D. Smith, the resident hydrographer, is in two sections. The lower section of the rod, reading from 15 to 25 feet, is nailed to the pile protection on the south bank of the river 50 feet below the Southern Pacific Railroad bridge. The upper section, reading above 24 feet, is a long pile on the north bank of the river 100 feet above the railway bridge, and is the original gage established in 1876. The bench mark is a standard United States Geological Survey bronze cap located at the railway bridge on the first pier from the south bank; elevation, 35.31 feet above the zero of the gage and 137.4 feet above sea level.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; Bull=Bulletin; WS=Water Supply Paper):

Description: Ann 18, iv, pp 298–299; Bull 131, p 51; 140, pp 207–208; WS 16, p 151; 28, p 133; 38, p 324; 50, p 387; 66, p 104; 85, p 17; 100, pp 19–20; 133, pp 25–26.
Discharge: Ann 18, iv, p 299; Bull 131, p 51; 140, p 208; 66, p 104; 85, p 18; 100, pp 20–24; 133, pp 26–29.
Discharge, mean daily: WS 133, p 31.
Discharge, monthly: WS 85, p 20; 100, p 25; 133, p 32.
Evaporation record: WS 133, p 32.
Gage heights: Bull 131, p 52; 140, pp 208–210; WS 11, p 73; 16, p 151; 28, p 141; 38, p 325; 50, p 387; 66, p. 104; 85, p 19; 100, pp 24–25; 133, p 30.
Hydrograph: Ann 12, ii, p 290.
Rating table: WS 85, p 19.

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*Discharge measurements of Colorado River at Yuma, Ariz., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec.-ft.* | | | *Feet.* | *Sec.-ft.* |
| January 4 | W. D. Smith | 18.60 | 3,985 | April 26 | W. D. Smitn | 23.40 | 37,160 |
| January 6 | do | 18.95 | 4,573 | April 27 | A. N. Kelly | 23.95 | 41,630 |
| January 9 | do | 18.65 | 4,170 | April 29 | W. D. Smith | 23.95 | 34,990 |
| January 10 | do | 21.10 | 16,090 | May 1 | do | 25.00 | 41,520 |
| January 11 | do | 19.20 | 6,401 | May 4 | do | 24.25 | 37,280 |
| January 13 | do | 19.25 | 6,348 | May 6 | do | 24.55 | 37,410 |
| January 17 | J. S. Evans | 22.30 | 20,420 | May 8 | do | 25.10 | 40,050 |
| January 18 | do | 23.95 | 27,450 | May 10 | do | 26.10 | 49,200 |
| January 20 | do | 21.00 | 12,170 | May 13 | do | 25.40 | 38,840 |
| January 23 | W. D. Smith | 20.20 | 7,863 | May 16 | do | 25.00 | 37,320 |
| January 25 | J. S. Evans | 19.80 | 7,055 | May 18 | do | 24.70 | 33,910 |
| January 28 | do | 19.55 | 5,727 | May 20 | do | 24.30 | 34,580 |
| January 31 | do | 19.30 | 5,278 | May 23 | do | 24.90 | 38,390 |
| February 2 | do | 19.60 | 6,054 | May 26 | do | 25.80 | 45,300 |
| February 4 | do | 19.70 | 6,632 | May 29 | do | 26.80 | 54,810 |
| February 6 | do | 21.40 | 16,600 | May 31 | do | 27.40 | 59,020 |
| February 8 | do | 28.00 | 67,730 | June 3 | do | 28.00 | 68,160 |
| February 9 | do | 28.75 | 82,820 | June 6 | do | 28.45 | 67,600 |
| February 10 | do | 26.20 | 39,580 | June 8 | do | 28.30 | 72,930 |
| February 11 | do | 24.10 | 32,120 | June 12 | do | 28.25 | 72,590 |
| February 16 | do | 21.50 | 18,610 | June 14 | do | 28.70 | 82,020 |
| February 18 | W. D. Smith | 21.40 | 16,490 | June 19 | do | 29.15 | 94,320 |
| February 20 | do | 25.10 | 47,000 | June 22 | do | 29.10 | 92,400 |
| February 22 | do | 25.80 | 54,730 | June 26 | do | 28.55 | 77,610 |
| February 23 | do | 23.70 | 32,990 | June 29 | do | 27.60 | 64,370 |
| February 24 | do | 22.05 | 21,990 | July 3 | do | 25.90 | 50,640 |
| February 25 | do | 21.50 | 18,860 | July 5 | do | 25.45 | 44,950 |
| February 27 | do | 23.45 | 27,730 | July 10 | do | 23.35 | 32,980 |
| March 1 | do | 23.95 | 29,070 | July 13 | F. R. S. Buttemer | 22.05 | 30,870 |
| March 2 | do | 24.90 | 39,260 | July 15 | do | 21.90 | 27,710 |
| March 3 | do | 26.70 | 70,170 | July 18 | do | 21.75 | 25,300 |
| March 6 | do | 24.80 | 44,310 | July 19 | do | 21.30 | 22,320 |
| March 9 | do | 24.10 | 36,400 | July 21 | do | 20.90 | 22,000 |
| March 11 | do | 24.20 | 38,625 | July 24 | do | 20.50 | 20,800 |
| March 13 | do | 24.45 | 38,870 | July 26 | do | 20.35 | 20,460 |
| March 15 | do | 24.00 | 36,720 | July 28 | do | 20.05 | 18,910 |
| March 16 | do | 26.10 | 60,640 | July 31 | do | 19.95 | 16,750 |
| March 17 | do | 27.35 | 65,820 | August 2 | do | 19.90 | 15,790 |
| March 19 | do | 28.00 | 73,440 | August 4 | do | 19.80 | 13,560 |
| March 20 | do | 30.25 | 110,800 | August 7 | do | 20.20 | 15,940 |
| March 22 | do | 28.90 | 91,200 | August 9 | do | 20.30 | 16,770 |
| March 23 | do | 27.75 | 76,930 | August 11 | do | 20.40 | 16,980 |
| March 24 | do | 25.60 | 58,600 | August 14 | do | 20.10 | 15,960 |
| March 25 | do | 24.10 | 43,050 | August 16 | do | 19.60 | 13,800 |
| March 27 | do | 23.10 | 31,020 | August 19 | W. D. Smith | 19.10 | 9,757 |
| March 30 | do | 22.00 | 24,390 | August 21 | do | 18.85 | 8,690 |
| April 1 | do | 21.50 | 20,690 | August 23 | do | 18.75 | 7,795 |
| April 3 | do | 21.30 | 19,480 | August 26 | do | 18.65 | 7,241 |
| April 5 | do | 21.60 | 21,000 | August 28 | do | 18.70 | 7,013 |
| April 7 | do | 22.50 | 29,840 | August 30 | do | 19.60 | 10,290 |
| April 13 | do | 25.30 | 45,800 | September 1 | do | 18.50 | 6,440 |
| April 14 | J. N. Johannson | 29.40 | 93,800 | September 4 | do | 18.45 | 6,464 |
| April 19 | W. D. Smith | 24.90 | 45,050 | September 6 | do | 18.30 | 5,644 |
| April 21 | do | 23.30 | 39,500 | September 9 | do | 18.45 | 6,051 |
| April 24 | do | 22.30 | 31,690 | September 11 | do | 18.95 | 7,631 |

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*Discharge measurements of Colorado River at Yuma, Ariz., in 1905*—Continued.

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec.-ft.* | | | *Feet.* | *Sec.-ft.* |
| September 13. | W. D. Smith..... | 18.85 | 7,706 | November 3.. | W. D. Smith..... | 18.50 | 5,812 |
| September 14. | .....do..... | 19.40 | 9,667 | November 6.. | .....do..... | 18.35 | 5,709 |
| September 16. | .....do..... | 18.80 | 7,700 | November 9.. | .....do..... | 18.75 | 6,632 |
| September 18. | .....do..... | 18.60 | 6,743 | November 13.. | .....do..... | 18.75 | 6,308 |
| September 20. | .....do..... | 18.70 | 7,131 | November 16.. | .....do..... | 18.85 | 6,787 |
| September 23. | .....do..... | 18.45 | 6,063 | November 23.. | .....do..... | 18.80 | 6,495 |
| September 26. | .....do..... | 18.20 | 5,260 | November 27.. | .....do..... | 19.00 | 6,652 |
| September 29. | .....do..... | 18.00 | 5,287 | November 30.. | .....do..... | 31.30 | 102,700 |
| October 2..... | .....do..... | 18.00 | 5,222 | December 1... | .....do..... | 28.78 | 77,360 |
| October 4..... | .....do..... | 18.65 | 7,172 | December 2... | .....do..... | 23.50 | 37,160 |
| October 6..... | .....do..... | 18.80 | 7,295 | December 5... | .....do..... | 21.30 | 28,650 |
| October 7..... | .....do..... | 20.10 | 13,080 | December 8... | .....do..... | 19.50 | 16,970 |
| October 10.... | .....do..... | 20.30 | 14,060 | December 11.. | .....do..... | 18.75 | 12,620 |
| October 13.... | .....do..... | 19.70 | 10,660 | December 14.. | .....do..... | 18.30 | 9,613 |
| October 16.... | .....do..... | 19.10 | 8,290 | December 16.. | .....do..... | 18.20 | 8,795 |
| October 19.... | .....do..... | 18.70 | 6,779 | December 18.. | .....do..... | 17.95 | 7,807 |
| October 23.... | .....do..... | 18.60 | 6,025 | December 21.. | .....do..... | 17.85 | 7,670 |
| October 27.... | .....do..... | 18.40 | 5,507 | December 26.. | .....do..... | 17.95 | 7,502 |
| October 31.... | .....do..... | 18.40 | 5,579 | December 30.. | .....do..... | 17.80 | 5,981 |

*Daily gage height, in feet, of Colorado River at Yuma, Ariz., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1..... | 18.5 | 19.45 | 23.9 | 21.5 | 25.0 | 27.55 | 26.8 | 19.95 | 18.5 | 18.0 | 18.4 | 28.05 |
| 2..... | 18.5 | 19.6 | 25.05 | 21.4 | 24.7 | 27.8 | 26.5 | 19.9 | 18.4 | 18.0 | 18.45 | 24.05 |
| 3..... | 18.5 | 19.7 | 26.7 | 21.3 | 24.7 | 28.0 | 25.9 | 19.85 | 18.4 | 18.3 | 18.5 | 23.95 |
| 4..... | 18.6 | 19.7 | 26.7 | 21.3 | 24.25 | 28.2 | 25.45 | 19.8 | 18.45 | 18.8 | 18.4 | 22.9 |
| 5..... | 18.75 | 20.3 | 25.3 | 21.65 | 24.25 | 28 35 | 25.45 | 19.8 | 18.4 | 19.0 | 18.35 | 21.3 |
| 6..... | 18.95 | 21.2 | 24.8 | 22.6 | 24.55 | 28.45 | 25.0 | 19.9 | 18.3 | 18.95 | 18.35 | 20.5 |
| 7..... | 19.0 | 21.05 | 24.8 | 22.5 | 24.7 | 28.55 | 24.6 | 20.3 | 18.2 | 20.05 | 18.4 | 20.0 |
| 8..... | 18.9 | 27.2 | 24.7 | 22.1 | 25.1 | 28.3 | 24.1 | 20.5 | 18.3 | 20.2 | 18.65 | 19.5 |
| 9..... | 18.65 | 28.75 | 24.1 | 22.0 | 25.75 | 28.2 | 23.8 | 20.3 | 18.45 | 20.6 | 18.75 | 19.2 |
| 10..... | 21.0 | 26.6 | 23.9 | 22.0 | 26.1 | 28.15 | 23.35 | 20.2 | 18.95 | 20.3 | 18.8 | 18.95 |
| 11..... | 19.25 | 24.1 | 24.1 | 21.85 | 26.3 | 28.2 | 22.8 | 20.45 | 18.7 | 20.1 | 18.8 | 18.75 |
| 12..... | 19.2 | 22.95 | 24.75 | 22.10 | 26.1 | 28.25 | 22.6 | 20.4 | 18.6 | 19.95 | 19.0 | 18.45 |
| 13..... | 19.25 | 22.4 | 24.35 | 25.45 | 25.5 | 28.4 | 22.1 | 20.15 | 18.85 | 19.7 | 18.75 | 18.4 |
| 14..... | 19.45 | 22.2 | 23.7 | 29.25 | 25.1 | 28.7 | 22.0 | 20.1 | 19.45 | 19.3 | 18.65 | 18.3 |
| 15..... | 19.65 | 22.25 | 24.35 | 29.65 | 25.0 | 28.7 | 21.9 | 19.75 | 19.2 | 19.2 | 18.75 | 18.2 |
| 16..... | 19.75 | 21.6 | 26.35 | 27.2 | 25.05 | 28.75 | 21.95 | 19.6 | 18.8 | 19.1 | 18.85 | 18.2 |
| 17..... | 22.2 | 21.1 | 27.35 | 24.9 | 24.95 | 28.85 | 22.25 | 19.35 | 18.65 | 18.9 | 18.85 | 18.0 |
| 18..... | 23.8 | 21.4 | 26.55 | 24.55 | 24.7 | 28.95 | 21.7 | 19.15 | 18.6 | 18.75 | 18.8 | 17.95 |
| 19..... | 22.2 | 22.65 | 28.1 | 24.9 | 24.5 | 29.15 | 21.3 | 19.05 | 18.6 | 18.7 | 18.95 | 17.9 |
| 20..... | 21.0 | 24.9 | 30.3 | 24.4 | 24.3 | 29.05 | 21.25 | 19.0 | 18.7 | 18.7 | 18.9 | 17.95 |
| 21..... | 20.45 | 25.75 | 29.75 | 23.3 | 24.45 | 29.10 | 20.95 | 18.85 | 18.6 | 18.65 | 18.8 | 17.8 |
| 22..... | 20.55 | 25.85 | 28.9 | 22.8 | 24.65 | 29.1 | 20.7 | 18.8 | 18.45 | 18.6 | 18.8 | 17.85 |
| 23..... | 20.3 | 23.55 | 27.75 | 22.6 | 24.85 | 29.0 | 20.5 | 18.75 | 18.45 | 18.6 | 18.8 | 17.85 |
| 24..... | 20.0 | 22.0 | 25.6 | 22.35 | 25.25 | 28.85 | 20.5 | 18.7 | 18.4 | 18.6 | 18.7 | 17.9 |
| 25..... | 19.8 | 21.45 | 24.1 | 22.6 | 25.55 | 28.75 | 20.45 | 18.65 | 18.35 | 18.6 | 18.75 | 17.85 |
| 26..... | 19.75 | 23.65 | 23.4 | 23.45 | 25.75 | 28.55 | 20.35 | 18.65 | 18.2 | 18.5 | 18.8 | 17.95 |
| 27..... | 19.65 | 23.5 | 23.1 | 23.95 | 26.0 | 28.25 | 20.2 | 18.7 | 18.0 | 18.4 | 19.05 | 17.9 |
| 28..... | 18.55 | 23.5 | 22.85 | 24.15 | 26.4 | 27.9 | 20.05 | 18.7 | 18.0 | 18.35 | 21.3 | 17.8 |
| 29..... | 19.4 | ..... | 22.4 | 23.95 | 26.8 | 27.6 | 19.95 | 18.65 | 18.0 | 18.4 | 26.2 | 17.8 |
| 30..... | 19.35 | ..... | 22.0 | 24.55 | 27.0 | 27.25 | 20.0 | 19.5 | 18.0 | 18.45 | 31.3 | 17.8 |
| 31..... | 19.3 | ..... | 21.9 | ..... | 27.4 | ..... | 19.95 | 18.8 | ..... | 18.4 | ..... | 17.8 |

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*Daily discharge, in second-feet, of Colorado River at Yuma, Ariz., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3,750 | 5,800 | 29,070 | 20,690 | 41,520 | 61,500 | 57,800 | 16,400 | 6,440 | 5,240 | 5,620 | 77,360 |
| 2 | 3,750 | 6,054 | 39,260 | 20,100 | 39,700 | 65,300 | 55,500 | 15,790 | 6,280 | 5,220 | 5,720 | 37,160 |
| 3 | 3,800 | 6,500 | 70,170 | 19,480 | 39,700 | 68,160 | 50,640 | 14,700 | 6,250 | 6,140 | 5,810 | 40,200 |
| 4 | 3,985 | 6,632 | 70,200 | 19,450 | 37,280 | 67,900 | 45,000 | 13,560 | 6,464 | 7,170 | 5,750 | 35,000 |
| 5 | 4,300 | 9,800 | 51,100 | 21,000 | 37,100 | 67,600 | 44,950 | 12,900 | 6,160 | 8,250 | 5,700 | 28,650 |
| 6 | 4,570 | 16,590 | 44,310 | 30,100 | 37,410 | 67,600 | 42,400 | 14,200 | 5,644 | 7,300 | 5,710 | 23,300 |
| 7 | 4,700 | 9,400 | 44,100 | 29,840 | 38,000 | 69,500 | 40,100 | 15,940 | 5,060 | 13,080 | 5,860 | 20,100 |
| 8 | 4,500 | 62,080 | 43,100 | 25,800 | 40,050 | 72,930 | 37,200 | 17,450 | 5,560 | 13,560 | 6,360 | 16,970 |
| 9 | 4,170 | 82,820 | 36,400 | 24,800 | 46,000 | 70,300 | 35,500 | 16,770 | 6,051 | 15,500 | 6,630 | 15,000 |
| 10 | 16,090 | 52,580 | 34,400 | 24,900 | 49,200 | 69,600 | 32,980 | 16,200 | 8,000 | 14,060 | 6,680 | 13,700 |
| 11 | 6,400 | 37,320 | 38,620 | 23,000 | 52,000 | 71,000 | 32,100 | 16,960 | 7,631 | 12,950 | 6,550 | 12,620 |
| 12 | 6,300 | 29,700 | 42,000 | 26,100 | 48,000 | 72,590 | 31,720 | 16,900 | 6,900 | 12,100 | 6,950 | 10,500 |
| 13 | 6,350 | 22,800 | 38,870 | 45,800 | 38,840 | 76,000 | 30,870 | 16,150 | 7,706 | 10,660 | 6,310 | 10,200 |
| 14 | 7,000 | 21,900 | 32,000 | 93,800 | 37,800 | 82,020 | 29,500 | 15,960 | 9,667 | 9,100 | 6,050 | 9,610 |
| 15 | 8,370 | 22,500 | 36,720 | 97,500 | 37,300 | 82,000 | 27,710 | 14,500 | 8,900 | 8,650 | 6,500 | 9,100 |
| 16 | 8,600 | 18,610 | 60,640 | 70,100 | 37,320 | 83,000 | 28,300 | 13,800 | 7,700 | 8,290 | 6,790 | 8,800 |
| 17 | 20,100 | 14,600 | 65,820 | 45,000 | 37,000 | 86,000 | 31,100 | 11,900 | 7,000 | 7,500 | 6,640 | 8,100 |
| 18 | 27,500 | 16,490 | 62,400 | 43,600 | 33,910 | 88,500 | 25,300 | 10,300 | 6,743 | 6,950 | 6,560 | 7,810 |
| 19 | 19,300 | 31,500 | 73,440 | 45,050 | 34,200 | 94,320 | 22,320 | 9,757 | 6,720 | 6,780 | 6,320 | 7,750 |
| 20 | 12,120 | 47,000 | 110,840 | 43,400 | 34,580 | 91,500 | 22,250 | 9,350 | 7,131 | 6,700 | 6,240 | 7,720 |
| 21 | 9,300 | 54,200 | 103,500 | 39,500 | 35,700 | 92,400 | 22,000 | 8,690 | 6,700 | 6,400 | 6,320 | 7,670 |
| 22 | 10,170 | 54,730 | 91,200 | 35,900 | 37,000 | 92,390 | 21,500 | 8,100 | 6,080 | 6,100 | 6,400 | 7,640 |
| 23 | 7,863 | 32,990 | 76,930 | 33,900 | 38,390 | 89,800 | 20,900 | 7,796 | 6,063 | 6,020 | 6,500 | 7,600 |
| 24 | 7,900 | 21,990 | 58,600 | 31,690 | 41,500 | 84,800 | 20,800 | 7,550 | 5,890 | 6,000 | 6,520 | 7,560 |
| 25 | 7,025 | 18,850 | 43,050 | 33,000 | 43,700 | 82,000 | 20,650 | 7,380 | 5,740 | 5,970 | 6,550 | 7,540 |
| 26 | 6,770 | 30,500 | 34,600 | 37,160 | 45,290 | 77,610 | 20,460 | 7,241 | 5,260 | 5,750 | 6,580 | 7,500 |
| 27 | 6,250 | 27,730 | 31,020 | 41,630 | 47,600 | 73,500 | 19,700 | 7,240 | 5,270 | 5,510 | 6,650 | 7,200 |
| 28 | 5,730 | 25,000 | 29,500 | 39,000 | 51,100 | 68,500 | 18,910 | 7,013 | 5,280 | 5,400 | 24,500 | 6,700 |
| 29 | 5,400 | ..... | 26,900 | 34,990 | 54,810 | 64,370 | 17,200 | 6,850 | 5,287 | 5,540 | 62,500 | 6,400 |
| 30 | 5,070 | ..... | 24,390 | 38,700 | 56,300 | 61,500 | 17,500 | 10,290 | 5,260 | 5,670 | 102,700 | 5,980 |
| 31 | 4,900 | ..... | 23,500 | ..... | 59,020 | ..... | 16,750 | 7,500 | ..... | 5,580 | ..... | 5,900 |

NOTE.—Daily discharge obtained by indirect method.

*Estimated monthly discharge of Colorado River at Yuma, Ariz., for 1905.*

[Drainage area, 225,000 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 27,500 | 3,750 | 8,130 | 499,900 | 0.036 | 0.042 |
| February | 82,820 | 5,800 | 28,100 | 1,561,000 | .125 | .130 |
| March | 110,800 | 23,500 | 50,540 | 3,108,000 | .225 | .259 |
| April | 97,500 | 19,450 | 37,830 | 2,251,000 | .168 | .187 |
| May | 59,020 | 33,910 | 42,170 | 2,593,000 | .187 | .216 |
| June | 94,320 | 61,500 | 76,470 | 4,550,000 | .340 | .379 |
| July | 57,800 | 16,750 | 30,310 | 1,864,000 | .135 | .156 |
| August | 17,450 | 6,850 | 12,100 | 744,000 | .054 | .062 |
| September | 9,667 | 5,060 | 6,495 | 386,500 | .029 | .032 |
| October | 15,500 | 5,220 | 8,037 | 494,200 | .036 | .042 |
| November | 102,700 | 5,620 | 12,000 | 714,000 | .053 | .059 |
| December | 77,360 | 5,900 | 15,400 | 946,900 | .068 | .078 |
| The year | 110,800 | 3,750 | 27,300 | 19,710,000 | .121 | 1.64 |

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*Yearly maximum and minimum gage heights, in feet, of Colorado River at Yuma, Ariz., 1878 to 1905.*

[Compiled from the records of Capt. Isaac Polhamus, the Southern Pacific Railroad, and the United States Geological Survey.]

| Year. | Maximum. | | Minimum. | | Year. | Maximum. | | Minimum. | |
|---|---|---|---|---|---|---|---|---|---|
| | Height. | Date. | Height. | Date. | | Height. | Date. | Height. | Date. |
| 1878..... | 23.0 | June 24 | 14.7 | Dec. 31 | 1892..... | 25.5 | July 3 | 15.5 | Dec. 31 |
| 1879..... | 20.0 | May 12 | 13.2 | Oct. 14 | 1893..... | 25.2 | May 28 | 15.5 | Jan. 2 |
| 1880..... | 24.0 | May 31 | 14.9 | Dec. 8 | 1894..... | 23.7 | June 14 | 15.9 | Jan. 23 |
| 1881..... | 23.5 | June 14 | 15.0 | Jan. 25 | 1895..... | 28.2 | Jan. 20 | 16.8 | Feb. 13 |
| 1882..... | 22.6 | June 18 | 15.5 | Dec. 20 | 1896..... | 24.5 | Sept. 30 | 17.4 | Dec. 17 |
| 1883..... | 24.5 | July 3 | 14.0 | Dec. 14 | 1897..... | 26.1 | June 9 | 17.9 | Dec. 21 |
| 1884..... | [a]28.5 | June 27 | 14.2 | Dec. 5 | 1898..... | 23.6 | June 27 | 17.5 | Jan. 8 |
| 1885..... | 24.7 | June 13 | 13.7 | Feb. 8 | 1899..... | 27.0 | July 1 | 17.0 | Oct. 17 |
| 1886..... | 26.8 | June 6 | 14.4 | Jan. 19 | 1900..... | 26.0 | June 10 | 16.4 | Sept. 10 |
| 1887..... | 23.5 | June 10 | 14.9 | Jan. 26 | 1901..... | 27.2 | May 31 | 16.2 | Jan. 14 |
| 1888..... | 21.8 | June 25 | 14.8 | Jan. 4 | 1902..... | 24.5 | May 26 | 16.6 | Sept. 28 |
| 1889..... | 22.4 | June 7 | 15.4 | Sept. 27 | 1903..... | 27.7 | June 26 | 16.8 | Jan. 13 |
| 1890..... | 25.5 | June 5 | 16.4 | Jan. 29 | 1904..... | 26.3 | June 5 | 18.3 | Dec. 27 |
| 1891..... | [b]33.2 | Feb. 26 | 16.4 | Sept. 22 | 1905..... | 31.3 | Nov. 30 | 17.8 | Dec. 31 |

[a] Said to be highest flood for 17 years preceding.

[b] Highest flood recorded.

## COLORADO RIVER BELOW HEADING NO. 3 OF THE IMPERIAL CANAL.

Measurements at this point were begun July 12, 1905, as so much water was at that date going down the canal that it was simpler and more economical to measure the water in the old channel of the Colorado than to continue the measurements on the canal itself.

In the center of the river, opposite heading No. 3, is an island nearly a mile long. The channel on the west side of the island is about 600 feet wide; that on the east side is about 800 feet wide. At first the discharge was measured at a point below the island, but by August 15 a sand bar had formed from the island to the west bank of the river below the heading, and all water passing down on the west of the island entered the canal. August 31 a gage was established above the head of the island, and after that date all discharge measurements were made at the head of the island. Measurements were not made at one certain point, but at any favorable cross section among the shifting bars of mud and quicksand that could be reached and measured by boat or by wading.

The old channel continued to silt up gradually and the new one to scour deeper, and October 20, 1905, all the water was carried by the new channel, i. e., the Imperial canal. The California Development Company made a serious and expensive effort to turn the water back by constructing a dam of piles, brush mats, brush, and sand bags. By the latter part of November this dam had progressed sufficiently to raise the height of the water 2.5 feet, and about 300 second-feet of water flowed down the old channel. Most of the great flood of November 29 at its crest went down the old channel; but by the time it had receded the dam was washed away, the old channel was silted up higher than before, and the new channel was scoured still deeper.

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The gage is a vertical rod nailed to the root of a large willow stump on the east bank of the river. It is located at a point nearly opposite the upper end of the upper row of piling, extending from the head of the island obliquely upstream to the west bank, and is opposite station 425 of the Yuma Valley levee line. The bench mark is a nail in a willow tree 20 feet above the gage and 25 feet from the bank; elevation, 13.05 feet above the zero of the gage. Levels from the levee line show the elevation of the zero of the gage to be 109.19 feet above sea level.

*Discharge measurements of Colorado River, below heading No. 3 of Imperial canal in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec.-ft.* | | | *Feet.* | *Sec.-ft.* |
| July 12 | W. D. Smith | | 11,610 | October 18 | W. D. Smith | 1.50 | 25 |
| July 30 | L. B. Brainard | | 2,484 | October 25 | do | 1.00 | [a]0 |
| August 3 | F. R. S. Buttemer | | 1,999 | October 30 | do | .95 | [a]0 |
| August 10 | do | | 2,218 | November 4 | do | .95 | [a]0 |
| August 18 | W. D. Smith | | 1,169 | November 11 | do | | [a]0 |
| August 24 | do | | 769 | November 18 | do | 2.10 | 87 |
| August 31 | do | 2.90 | 557 | November 25 | do | 2.45 | 205 |
| September 7 | do | 1.80 | 90 | November 30 | J. A. Tolin | | [b]70,000 |
| September 14 | do | 3.80 | 1,232 | December 7 | W. D. Smith | | 878 |
| September 22 | do | 2.10 | 175 | December 13 | do | | [c]0 |
| September 28 | do | 1.60 | 37 | December 17 | do | | [c]0 |
| October 11 | do | 3.50 | 1,014 | December 23 | do | | [a]0 |

[a] No discharge October 20 to November 11. [b] Estimated. [c] No discharge December 13–31.

## CANALS BELOW YUMA, ARIZ.

### COLORADO VALLEY PUMPING AND IRRIGATION COMPANY'S CANAL AT YUMA, ARIZ.

This canal diverts water from the Colorado River at Yuma, Ariz., for the purpose of irrigating land in the upper part of Yuma Valley. The water is raised by a large centrifugal pump operated by a steam engine of 125 horsepower. The lift varies from 2 to 12 feet in ordinary seasons. The expense of pumping is about $0.60 per acre-foot, not including interest on investment and deterioration of plant. The amount of water used during 1904 was accurately determined by W. D. Smith, and reported in Water-Supply Paper No. 134, page 42, under the head of "Duty of water and seepage investigations." Measurements made in 1903 are reported in Water-Supply Paper No. 100. During 1905 the zanjero used the same "irrigating head" as for the year preceding, his measurements being made by weirs. This was checked by a meter gaging on September 26, which gave a discharge of 34.1 second-feet. The engineer, H. H. Alexander, kept a record of the number of irrigating heads pumped every hour the pump was in operation during 1905. The following table is based on his record. The rainfall data were furnished by S. H. Hackett, of the United States Weather Bureau.

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*Monthly duty of water of the Colorado Valley Pumping and Irrigation Company's canal and rainfall at Yuma, Ariz., for 1905.*

| | Duty of water (acre-feet). | | | Rainfall (inches). |
|---|---|---|---|---|
| | Total. | Per acre, gross area. | Per acre, net area. | |
| January | 220 | 0.03 | 0.10 | 1.15 |
| February | 250 | .04 | .11 | 3.43 |
| March | 0 | .00 | .00 | 3.33 |
| April | 1,180 | .18 | .51 | .16 |
| May | 1,470 | .23 | .64 | .00 |
| June | 1,240 | .19 | .54 | .00 |
| July | 1,260 | .19 | .55 | .00 |
| August | 1,550 | .24 | .67 | .02 |
| September | 1,310 | .20 | .57 | .52 |
| October | 530 | .08 | .23 | .02 |
| November | 350 | .05 | .15 | 2.44 |
| December | 300 | .05 | .13 | .32 |
| Total irrigation | 9,660 | 1.48 | 4.20 | 11.39 |
| Total, including rainfall | | | 5.15 | |

Mixed crops: Alfalfa, 1,350 acres; grain, 470 acres; corn and sorghum, 250 acres; miscellaneous, 230 acres. Total net area, 2,300 acres; total gross area, 6,500 acres; number of irrigators, 75. Average annual rainfall at Yuma, 3 inches.

The above includes loss by seepage.

### FARMERS' CANAL NEAR YUMA, ARIZ.

This canal, the property of the Yuma Valley Union Land and Water Company, diverts water from Colorado River at a point 1 mile below Yuma, Ariz., for the purpose of irrigating lands in Yuma Valley.

Measurements have been made at the heading immediately at the river since May, 1903, by means of a boat and cable or by wading. As the point of gaging is above the controlling head gate, gage heights would be of no value for the purpose of constructing rating tables and no gage has been established. The height at any date may be obtained approximately by subtracting 1 foot from the gage reading at Yuma.

The canal is heavily silted, and during 1905 has been dry much of the time.

Results of measurements made in previous years are contained in Water-Supply Papers Nos. 100 and 134 of the United States Geological Survey.

*Discharge measurements of Farmers' Canal near Yuma, Ariz., for 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Discharge. |
|---|---|---|---|---|
| | | *Sq. feet.* | *Ft. per sec.* | *Sec.-ft.* |
| January 13 | W. D. Smith | 31 | 0.71 | 22 |
| March 7 | do | 31 | .58 | 18 |
| May 11 | do | 67 | 1.91 | 128 |
| June 30 | do | 37 | 2.27 | 84 |

### LUDY CANAL NEAR YUMA, ARIZ.

This canal is the property of the Irrigation Land and Improvement Company. It diverts water from Colorado River at a point 3 miles below Yuma, Ariz., for the purpose of irrigating lands in Yuma Valley.

Miscellaneous measurements have been made at the heading since March, 1903. June 6, 1905, a gage was established and a nilometer placed on the canal by W. D. Smith, at the

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second gate and bridge, which is 1 mile from the river. No water is taken from the cana above this gate. The gage is nailed to the west wall of the flume below the bridge. The bench mark is a nail driven into the top of the west end of an 8 by 8 inch timber at the lower side of the bridge. Its elevation is 15.00 feet above the zero of the gage. The elevation of the top of the floor of the bridge at the southwest corner is 16.10 feet above the zero of the gage. Discharge measurements are made from the lower side of the bridge. The initial point is the east end of the 8 by 8 inch timber referred to above. The canal is straight both above and below the gate. The velocity of the cross section is fairly uniform. The gage height is not affected by any gates farther down the canal.

The canal is badly silted up and is dry much of the time at low water. During the floods of 1905 the banks were overflowed and considerably damaged.

*Discharge measurements of Ludy canal near Yuma, Ariz., for 1905.*

| Date. | Hydrographer. | Area. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 21 | W. D. Smith | 405 | 0.90 | ..... | 365 |
| April 6 | ....do | 128 | .18 | ..... | 23 |
| May 5 | ....do | 104 | .64 | ..... | 67 |
| June 6 | ....do | 174 | 1.97 | ..... | 343 |
| June 17 | ....do | 709 | 2.42 | 12.60 | 1,932 |
| July 11 | ....do | 235 | 1.15 | 10.40 | 271 |
| July 15 | ....do | 152 | .19 | 9.30 | 29 |

## IMPERIAL CANAL AT HEADINGS IN UNITED STATES AND MEXICO.

*General statement.*—The original heading of the Imperial canal, designated in the following tables as heading No. 1, is located about 10 miles by Colorado River below Yuma, Ariz., on the California side, immediately above the international boundary line and opposite Pilot Knob Mountain. The California Development Company is now constructing a permanent gate on bed rock at a spur of this mountain in place of the wooden one now in use. During the summer of 1904 a second heading was made immediately below the boundary line, and in October of the same year an opening was made to the river at a point 4 miles below the boundary. This last opening is designated as heading No. 3. No gage was placed at either heading No. 2 or No. 3. The canal runs parallel to the river for the first 4 miles of its course, so that it was necessary to cut a channel only one-half mile long.

The first 12 miles of the canal was constructed; the remaining 40 miles is an old natural channel, called Alamo River. The whole length of the canal lies in the Colorado River delta, which is composed of loose, sandy soil, covered with a heavy growth of mesquite, willow, and arrowwood. The canal as a whole had a greater fall per mile than the river, but for the first 15 miles the fall was less than that in the river, and for this reason the canal had to be dredged constantly to keep it open. The exceptional floods of January, February, March, and April, 1905, scoured it out to a channel of considerable depth, and during the regular annual flood of May and June, which was unusually high and long, this scouring was continued to such an extent that when the flood began to recede and the river again began to deposit mud, the velocity in the canal was much greater than in the river below heading No. 3. The result was that the old river channel silted up heavily while the new channel, the canal from heading No. 3 down, was still scouring. As the old river channel filled with silt a greater proportion of the water went down the canal, increasing the velocity; and as the canal scoured deeper the amount and velocity of the water going down the old channel were decreased. These reactions were so great that the process of scouring a new channel, which had been going on slowly for several months, began to make rapid progress. The canal was widened in a few days from 100 to 300 or 400 feet. June 30 the total discharge of the river was 61,500 second-feet, 22 per cent of which went down the canal; July 8 the total

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discharge was 37,200 second-feet, 67 per cent of which went down the canal. All efforts to stop the flood proved ineffectual.

Meter measurements have been made weekly during the year to determine the total amount of water diverted by the canal, the amount diverted in the United States, the amount diverted in Mexico, and the amount going down the old river channel.

Besides miscellaneous gagings farther down the canal, measurements were made at five points, as follows: Heading No. 1, heading No. 2, heading No. 3 above its junction with the original canal (giving discharge of heading No. 3 alone), heading No. 3 below the junction (giving the total discharge of the canal), and the old channel of the Colorado below heading No. 3. At all of these stations except the last the conditions are constantly changing. The banks are washing away or being filled in, and the bed is silting up or scouring out and being dredged out. For these reasons it has been necessary to put in new gages often. The frequent passage of barges and dredges has rendered the maintenance of permanent cables impracticable, and a light cable has been stretched for each gaging. Measurements each week have been made at such points as would give the desired results, directly or indirectly, with the least expenditure of time and money.

The total discharge of the canal during 1905 was obtained as follows: From January 1 to March 10 by direct meter measurements at heading No. 3 below the junction; from March 11 to June 30 by adding discharges of headings Nos. 1, 2, and 3; from July 1 to December 31 by subtracting the discharge of the old channel below heading No. 3 from the discharge of Colorado River at Yuma. To obtain the discharge of the old channel below heading No. 3 on the dates when it was not measured directly, the total discharge of the canal was subtracted from the discharge of the Colorado at Yuma.

The mean discharge of heading No. 1 for each month was obtained by averaging results of meter measurements. The mean discharge of the whole canal for each month was obtained in the same way. Measurements for the first ten months are so well distributed that they are given equal weight. On account of the flood of November 29, the estimate for November and December is based on an interpolation of the percentage of the total flow of the river diverted by the canal. As the flood in the old channel lasted only five days, any error from this method of calculation is not great.

The monthly summary of the discharge of headings Nos. 2 and 3, showing total diversion made in Mexico, is obtained by subtracting the discharge of heading No. 1 from the total. The monthly summary of the discharge of the old channel below heading No. 3 is obtained by subtracting the total discharge of the canal from the discharge of Colorado River at Yuma.

No gage observer was obtainable for the three lower stations, but gage-height records were kept at headings Nos. 1 and 2.

June 15, 1904, a waste gage was put in operation at a point 12 miles below heading No. 1, called the Quail River waste gate. Water going through this gate passes through Quail River into Padrones River and thence into Volcano Lake. Volcano Lake has two outlets—New River, which discharges into Salton Basin, and Hardy River, which discharges into the Gulf of California through the old channel of the Colorado. March 20, 1905, the flood silted up the channel leading from the waste gate and no more water has been diverted from the canal at this point.

After the flood of November 29, 1905, a channel was dredged from the canal to Quail River from a point 15 miles below heading No. 1, and a considerable amount of water diverted to Padrones River and Volcano Lake. All the water going down the canal past this point discharges through Alamo and New rivers into Salton Basin, except what is lost by seepage and used for irrigation in the Imperial Valley.

The results of the discharge measurements made at the two waste channels mentioned above will be found in the list of miscellaneous discharge measurements.

*Heading No. 1.*—This station was established October 24, 1903. It is located half a mile from the river, 600 feet below the wooden head gates, and is 10 miles by river below Yuma, Ariz., on the California side.

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The channel is straight for 600 feet above and 300 feet below the cable and has a width of 70 feet. The right bank is low and is liable to overflow; the left bank has an elevation of 6 feet above high water. The bed of the canal is composed of silt and sand, is free from vegetation, and is very unstable. There is but one channel at all stages, but when the gage at Yuma reads about 26 feet the river overflows into the channel below the gaging section. The current has a moderate velocity.

Discharge measurements are made by means of a boat and cable. The initial point for soundings is a charred post at the southeast corner of the corral about 150 feet west of the right bank.

A vertical gage, which is read twice each day by J. S. Carter, is located just above the international boundary line, on the right bank. The gage is referred to bench marks as follows: (1) A standard United States Geological Survey iron bench-mark post, located near monument 207 of the United States and Mexico boundary line, on a hill about half a mile west of the gaging station; elevation, 52.41 feet above the zero of the gage and 155 feet above sea level. (2) A nail in a tree on the right bank; elevation, 15.20 feet above the zero of the gage. (3) A nail in a post near the ground on the right bank near the corral; elevation, 14.90 feet above the zero of the gage.

The canal at this heading is filled with mud and has been temporarily abandoned, but some flood water passed through it during 1905 and was carefully measured.

*Heading No. 2.*—This heading diverts water from Colorado River at a point in Mexico 50 feet below the international boundary line, 400 feet below heading No. 1, and 10 miles by river from Yuma, Ariz. The station was established January 12, 1905, and weekly discharge measurements were made until August 31, 1905.

The channel is straight for 200 feet above and 600 feet below the cable and is about 80 feet wide. The bed and banks are composed of clay and silt and are unstable. There is but one channel at all stages, but when the gage in Yuma reads about 28 feet the river overflows into the canal below the gaging section. As the canal from heading No. 1 joins this canal about 800 feet below the gage rod, the two gages read about the same.

Discharge measurements are made by means of a boat and cable. The initial point for soundings is a clump of three willow trees growing near the north bank 200 feet below the gage.

A vertical rod gage, which is read daily by A. H. Chance, is driven into the north bank of the canal at a point 50 feet from the river. The bench marks and the elevation of the zero of the gage are the same as for heading No. 1.

*Heading No. 3 (above the junction).*—This heading or intake is in Mexico, 4 miles below the California-Mexico boundary line and 14 miles by Colorado River below Yuma, Ariz. The station was established March 8, 1905. The point of gaging is about one-half mile from the river and 150 feet above the junction of heading No. 3 with the original canal. Gagings at this point give the discharge of heading No. 3 alone.

The channel is straight for 500 feet above the point of gaging and nearly straight for 500 feet below. In the highest floods the banks are overflowed both above and below the station. The cross section is regular, the bed is unstable, and the current is swift. During July, 1905, the flood widened the channel from 100 to 300 feet and lowered the bed about 10 feet.

Discharge measurements are made by means of a boat and cable. The initial point for soundings, a willow stake on the north bank, was washed away by the flood in July, 1905.

The gage and bench marks are the same as for heading No. 3 below the junction, described below. The gage height is an indication of the total discharge of the canal and not of this heading alone.

*Heading No. 3 (below the junction).*—This station was established October 7, 1904. The point of gaging is about one-half mile from the river and 300 feet below the junction of heading No. 3 with the original canal. Gagings at this point give the total discharge of the canal.

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The channel is straight for 300 feet above and 500 feet below the cable. The banks are subject to overflow. The cross section is regular. The bed of the canal is composed of silt and sand and is very unstable. During July, 1905, the canal, which at this point was about 100 feet wide, was scoured out to a width of 400 feet and the depth increased about 8 feet.

Discharge measurements are made by means of a boat and cable.

The gage is a vertical rod on the south bank and is referred to bench marks as follows: (1) A nail in the central one of three willow trees 20 feet from the bank and 100 feet above the gage; elevation, 15.83 feet above the zero of the gage. This bench mark was originally 2 feet above the surface of the ground but is now 2 feet below, as soil was deposited here to a depth of about 4 feet by the flood of March 20, 1905. (2) A nail on the north side of a large willow stump 100 feet south of the south bank and 500 feet upstream from the gage; elevation, 22.26 feet above the zero of the gage.

Information in regard to this canal is contained in the following Water-Supply Papers of the United States Geological Survey: 85, p. 77; 100, pp. 27-29; 134, pp. 26-39.

*Discharge measurements made at the Imperial canal headings during 1905.*

| Date. | Heading No. 1. | Heading No. 2. | Heading No. 3. | | Total discharge of canal. |
|---|---|---|---|---|---|
| | | | Above junction. | Below junction. | |
| January 12 | | 380 | | 900 | 900 |
| January 26 | 90 | 350 | | 990 | 990 |
| February 8 | | | | 6,690 | 6,690 |
| February 14 | 460 | 900 | | 2,480 | 2,480 |
| February 28 | | | | 3,100 | 3,100 |
| March 8 | 1,110 | 1,530 | 1,180 | 3,600 | 3,600 |
| March 18 | 1,270 | 2,200 | 1,530 | | 5,000 |
| March 21 | 2,590 | 2,240 | 1,920 | | 6,750 |
| March 28 | 530 | 1,180 | 1,750 | | 3,460 |
| April 6 | 450 | 1,190 | 1,650 | | 3,290 |
| April 20 | 760 | 1,190 | 2,610 | | 4,560 |
| April 27 | 460 | 1,100 | | | |
| May 3 | 180 | 1,470 | 3,360 | | 5,010 |
| May 11 | | 1,940 | 4,160 | | 6,100 |
| May 17 | | 1,580 | 3,780 | | 5,360 |
| May 25 | | 1,790 | 3,560 | | 5,350 |
| June 1 | | 2,240 | 4,500 | | 6,740 |
| June 7 | | 2,660 | 5,830 | | 8,490 |
| June 15 | | 2,700 | 6,130 | | 8,830 |
| June 23 | | 3,260 | 6,880 | | 10,140 |
| June 30 | 390 | 3,140 | 10,430 | | 13,960 |
| July 8 | | | | [a] 25,000 | [a] 25,000 |
| July 20 | | 1,720 | 15,480 | | 17,200 |
| July 25 | | | 11,220 | | |
| August 3 | | 840 | | | |
| August 10 | | 750 | | | |
| August 18 | | 480 | | | |
| August 24 | | 440 | | | |
| August 31 | | 470 | | | |

[a] Estimated.

NOTE.—Figures in first four columns represent measurements; figures in fifth column are derived from the preceding. For discharge of canal July 25 to December 31, see following table.

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*Portion of Colorado River diverted by Imperial canal during 1905.*

| Date. | Discharge of Colorado River in second-feet. | | Diversion by Imperial canal. | |
|---|---|---|---|---|
| | At Yuma. | Below heading No. 3. of Imperial canal. | Second-feet. | Per cent. |
| January 12 | 6,300 | 5,400 | 900 | 14 |
| January 26 | 6,770 | 5,780 | 990 | 15 |
| February 8 | 62,080 | 55,390 | 6,690 | 11 |
| February 14 | 21,900 | 19,420 | 2,480 | 11 |
| February 28 | 25,000 | 21,900 | 3,100 | 12 |
| March 8 | 43,100 | 39,500 | 3,600 | 8 |
| March 18 | 62,400 | 57,400 | 5,000 | 8 |
| March 21 | 103,500 | 96,750 | 6,750 | 7 |
| March 28 | 29,500 | 26,040 | 3,460 | 12 |
| April 6 | 30,100 | 26,810 | 3,290 | 11 |
| April 20 | 43,400 | 38,840 | 4,560 | 11 |
| May 3 | 39,700 | 34,690 | 5,010 | 13 |
| May 11 | 52,000 | 45,900 | 6,100 | 12 |
| May 17 | 37,000 | 31,640 | 5,360 | 14 |
| May 25 | 43,700 | 38,350 | 5,350 | 12 |
| June 1 | 61,500 | 54,760 | 6,740 | 11 |
| June 7 | 69,500 | 61,010 | 8,490 | 12 |
| June 15 | 82,000 | 73,170 | 8,830 | 11 |
| June 23 | 89,800 | 79,660 | 10,140 | 11 |
| June 30 | 61,500 | 47,540 | 13,960 | 23 |
| July 8 | 37,200 | 12,200 | [a] 25,000 | 67 |
| July 12 | 31,720 | 11,610 | 20,110 | 63 |
| July 20 | 22,250 | 5,050 | 17,200 | 77 |
| July 25 | 20,650 | [a] 8,150 | [a] 12,500 | 61 |
| July 30 | 17,500 | 2,480 | 15,020 | 86 |
| August 3 | 14,700 | 2,000 | 12,700 | 86 |
| August 10 | 16,200 | 2,220 | 13,980 | 86 |
| August 18 | 10,300 | 1,170 | 9,130 | 89 |
| August 24 | 7,550 | 770 | 6,780 | 90 |
| August 31 | 7,500 | 560 | 6,940 | 93 |
| September 7 | 5,060 | 90 | 4,970 | 98 |
| September 14 | 9,670 | 1,230 | 8,440 | 87 |
| September 22 | 6,080 | 180 | 5,900 | 97 |
| September 28 | 5,280 | 40 | 5,240 | 99 |
| October 11 | 12,950 | 1,010 | 11,940 | 92 |
| October 18 | 6,950 | 25 | 6,925 | 99½ |
| October 25 | 5,970 | ..... | 5,970 | 100 |
| October 30 | 5,670 | ..... | 5,670 | 100 |
| November 4 | 5,750 | ..... | 5,750 | 100 |
| November 11 | 6,550 | ..... | 6,550 | 100 |
| November 18 | 6,560 | 90 | 6,470 | 99 |
| November 25 | 6,550 | 200 | 6,350 | 97 |
| November 30 | 102,700 | [a] 70,000 | [a] 32,700 | 32 |
| December 7 | 20,100 | 880 | 19,220 | 96 |
| December 13 | 10,200 | ..... | 10,200 | 100 |
| December 17 | 8,100 | ..... | 8,100 | 100 |
| December 23 | 7,600 | ..... | 7,600 | 100 |
| December 31 | 5,900 | ..... | 5,900 | 100 |

[a] Approximate.

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*Estimated monthly discharge of Imperial canal during 1905.*

| Month. | Heading No. 1, including total diversion in United States. | | Headings Nos. 2 and 3, including total diversion in Mexico. | | Total discharge. | |
|---|---|---|---|---|---|---|
| | Second-feet. | Total in acre-feet. | Second-feet. | Total in acre-feet. | Second-feet. | Total in acre-feet. |
| January | 45 | 2,770 | 900 | 55,330 | 945 | 58,100 |
| February | 460 | 25,550 | 3,630 | 201,600 | 4,090 | 227,200 |
| March | 1,370 | 84,240 | 3,330 | 204,800 | 4,700 | 289,000 |
| April | 555 | 33,020 | 3,370 | 200,500 | 3,925 | 233,600 |
| May | 20 | 1,230 | 5,435 | 334,200 | 5,455 | 335,400 |
| June | 200 | 11,900 | 9,430 | 561,100 | 9,630 | 573,000 |
| July | 130 | 7,990 | 17,840 | 1,097,000 | 17,960 | 1,105,600 |
| August | | | 9,905 | 609,000 | 9,905 | 609,000 |
| September | | | 6,140 | 365,400 | 6,140 | 365,400 |
| October | | | 7,625 | 468,800 | 7,625 | 468,800 |
| November | | | 8,400 | 500,000 | [a] 8,400 | [a] 500,000 |
| December | | | 12,200 | 750,000 | [a] 12,200 | [a] 750,000 |
| The year | 232 | 166,700 | 7,350 | 5,348,000 | 7,582 | 5,514,000 |

[a] Approximate.

## IMPERIAL VALLEY CANALS.

In July, 1904, stations were established on all canals entering the Imperial Valley, as follows: Holt canal, Hemlock canal, Alamo channel, Alamitos canal, Main canal, and Boundary canal. These stations are located on United States territory, and each is near the California-Mexico boundary line.

Discharge measurements are made from footbridges constructed at each station.

The gages are vertical 4 by 4 inch timbers substantially embedded in the ground. Automatic water-stage registers, from which the daily gage-height record is compiled, were placed at the first five stations mentioned above. These canals enter the valley east of Calexico, Cal.

In October a canal, known as canal No. 6, or Wisteria canal, was completed, which enters the valley west of Calexico, Cal. A station was established on this canal in November and weekly discharge measurements made. After April 11, 1905, the Holt canal supplied a much larger district than originally, covering territory which had been taking its supply from Alamo channel, near Eastside levee. A new canal, known as New Holt or No. 7, was built to replace the Holt, and a station was established in May. A station was also established on the Tamareck canal in June. The latter canal diverted water from New River to a district on the west side of New River below Imperial, which formerly obtained its supply from Main canal. Gages were established at both of these stations, but no automatic registers were placed on either canal.

The station on Alamo channel was inaccessible after the end of February on account of the flooded condition of the country. Water was not taken from the Alamo for irrigation after March. Discharge measurements were also made at Rockwood, on Alamo River, but no gage heights were kept. They show the amount of water flowing through this channel to Salton Sea.

Measurements were made at Brawley, on New River, for a similar purpose. They were made under such difficulties, however, that they are of little value. Measurements made at Calexico were used to determine the waste into Salton Sea, since the only diversion was through Tamarack canal. A large quantity of water was wasted from Main canal into New River below the gaging station at Calexico; this waste was measured and added to the discharge of New River in making estimate of total discharge of New River into Salton Lake.



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A description of these stations, with gage height and discharge data, is contained in Water-Supply Paper No. 134, United States Geological Survey, pages 29–39.

*Discharge measurements of Holt canal, near Calexico, Cal., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec.-ft.* | | | *Feet.* | *Sec.-ft.* |
| January 4 | W. V. Hardy | 1.30 | 19.5 | June 26 | R. R. McCoslin | 1.64 | 50 |
| January 12 | do | 1.41 | 30 | July 3 | do | 0.38 | 6.9 |
| January 19 | do | 1.43 | 28 | July 10 | do | .33 | 6.1 |
| January 26 | do | 1.23 | 19.5 | July 17 | do | .35 | 5.8 |
| February 2 | do | 1.23 | 18.1 | July 24 | do | .36 | 4.8 |
| February 9 | do | 1.07 | 13.5 | July 31 | do | .36 | 4.2 |
| February 17 | do | 1.90 | 40 | August 7 | do | 1.45 | 30 |
| February 24 | do | .93 | 11.1 | August 14 | do | 1.25 | 38 |
| March 13 | R. R. McCoslin | 1.88 | 51 | August 21 | do | ..... | 85 |
| March 20 | do | 2.06 | 64 | August 21 | do | .039 | 5.1 |
| March 27 | do | 2.84 | 118 | August 28 | do | 2.62 | 133 |
| April 3 | do | 2.81 | 131 | September 4 | do | 2.67 | 131 |
| April 10 | do | 1.13 | 21 | October 10 | W. V. Hardy | 3.08 | 169 |
| April 17 | do | 3.70 | 246 | October 17 | do | .25 | 2 |
| April 24 | do | 3.70 | 256 | October 23 | do | 2.65 | 128 |
| May 1 | do | 3.37 | 202 | November 6 | do | 1.40 | 21 |
| May 8 | do | 2.76 | 143 | November 13 | do | 1.51 | 35 |
| May 15 | do | 2.91 | 163 | November 20 | do | 1.33 | 40 |
| May 22 | do | 2.92 | 169 | November 29 | do | 1.31 | 22 |
| May 29 | do | 2.70 | 128 | October 30 | do | 2.55 | 124 |
| June 5 | do | 2.86 | 150 | September 11 | do | 2.88 | 159 |
| June 12 | do | 3.02 | 177 | September 25 | do | 2.75 | 128 |
| June 18 | do | 1.69 | 57 | October 2 | do | 2.80 | 137 |

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*Mean daily gage height, in feet, of Holt canal, near Calexico, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | (1.0) | 1.25 | 1.4 | 2.85 | 3.3 | 2.8 | 0.0 | 0.35 | 3.05 | 2.8 | 2.0 | 1.3 |
| 2 | (1.0) | 1.25 | 1.3 | 2.9 | 3.25 | 2.85 | .0 | .35 | 3.0 | 2.8 | 1.7 | 2.6 |
| 3 | (1.2) | 1.25 | (1.45) | 2.8 | 3.3 | 2.8 | .4 | .35 | 2.75 | 2.8 | 1.7 | 2.8 |
| 4 | (1.3) | 1.25 | (1.6) | 2.5 | 3.2 | 2.6 | .35 | .5 | 2.65 | 2.85 | 1.7 | 3.0 |
| 5 | (1.3) | 1.25 | (1.4) | 2.6 | 2.9 | 2.85 | .35 | 1.15 | 2.7 | 2.85 | 1.5 | 3.0 |
| 6 | (1.5) | 1.3 | 1.4 | 3.05 | (2.75) | 2.95 | .35 | 1.45 | 2.9 | 2.95 | 1.4 | 2.95 |
| 7 | (1.5) | 1.15 | 1.55 | (3.3) | (2.75) | 3.0 | .35 | 1.55 | 2.7 | 3.1 | 1.35 | 2.9 |
| 8 | (1.5) | (1.1) | 1.7 | (3.25) | 2.75 | 2.95 | .35 | 1.65 | 2.5 | 3.1 | 1.35 | 2.9 |
| 9 | (1.5) | 1.05 | 1.8 | (3.25) | 2.75 | 3.0 | .35 | 1.65 | 2.75 | 3.15 | 1.35 | 2.85 |
| 10 | (1.5) | 1.05 | 1.65 | 2.15 | 2.75 | 3.05 | .35 | 1.65 | 2.85 | 3.05 | 1.4 | 2.7 |
| 11 | (1.5) | 1.05 | (1.8) | 3.6 | 2.75 | 3.0 | .35 | 1.55 | 2.9 | 3.15 | 1.45 | 2.7 |
| 12 | 1.4 | 1.0 | (1.9) | 3.65 | 2.8 | 2.95 | .35 | 1.35 | 3.0 | 1.25 | 1.5 | ..... |
| 13 | 1.4 | 1.2 | 1.95 | 3.6 | 2.9 | 2.6 | .35 | 1.3 | 3.1 | .25 | 1.55 | ..... |
| 14 | 1.35 | 1.4 | 2.0 | 3.55 | 2.9 | 2.5 | .35 | 1.25 | 3.05 | .25 | 1.7 | ..... |
| 15 | 1.35 | 1.6 | 1.55 | 3.65 | 2.85 | 2.5 | .35 | 1.1 | 3.0 | .25 | 1.1 | ..... |
| 16 | 1.35 | 1.75 | 1.3 | 3.65 | 2.9 | 2.5 | .35 | .95 | 3.1 | .25 | .95 | ..... |
| 17 | 1.35 | 1.8 | 1.5 | 3.7 | 2.85 | 2.5 | .35 | .95 | 3.15 | .25 | .9 | ..... |
| 18 | 1.35 | 1.35 | 1.55 | 3.8 | 2.85 | 1.75 | .35 | .95 | 3.1 | .25 | .9 | ..... |
| 19 | 1.4 | 1.4 | 1.95 | 3.75 | 2.9 | 1.7 | .35 | 1.0 | 2.6 | .25 | .85 | ..... |
| 20 | 1.55 | 1.4 | 1.8 | 3.8 | 2.9 | 1.65 | .35 | 1.0 | 2.3 | 1.2 | 1.05 | ..... |
| 21 | 1.65 | 1.4 | 1.85 | 3.75 | 2.95 | 1.65 | .35 | 1.05 | 2.75 | 1.3 | .95 | ..... |
| 22 | 1.7 | 1.4 | 2.05 | 3.75 | 2.95 | 1.6 | .35 | 1.5 | 2.95 | 1.5 | .9 | ..... |
| 23 | 1.6 | 1.4 | 2.2 | 3.75 | 2.7 | 1.65 | .35 | 1.95 | 2.9 | 2.65 | .95 | ..... |
| 24 | (1.45) | .95 | 2.35 | 3.7 | 2.6 | 1.6 | .35 | 2.0 | 2.8 | 2.65 | 1.0 | ..... |
| 25 | 1.3 | 1.1 | 2.2 | 3.5 | 2.5 | 1.65 | .35 | 2.0 | 2.0 | 2.7 | .95 | ..... |
| 26 | (1.25) | 1.4 | (2.6) | 3.35 | 2.45 | 1.65 | .35 | 2.0 | 1.35 | 2.7 | .95 | ..... |
| 27 | 1.1 | 1.55 | 2.85 | 3.35 | 2.5 | 0 | .35 | 2.0 | 2.25 | 2.7 | 85 | ..... |
| 28 | .95 | 1.5 | 2.8 | 3.35 | 2.55 | 0 | .35 | 2.6 | 2.8 | 2.7 | .8 | ..... |
| 29 | 1.0 | ..... | 2.6 | 3.35 | 2.9 | 0 | .35 | 2.7 | 2.8 | 2.6 | .9 | ..... |
| 30 | (1.1) | ..... | 2.7 | 3.35 | 2.7 | 0 | .35 | 2.75 | 2.8 | 2.4 | 1.25 | ..... |
| 31 | (1.2) | ..... | 2.80 | ..... | 2.65 | ..... | .35 | 2.85 | ..... | 2.3 | ..... | ..... |

NOTE.—Gage heights in parentheses are estimated.

*Estimated monthly discharge of Holt canal near Calexico, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum | Minimum | Mean. | |
| January | 40 | 10 | 24.8 | 1,525 |
| February | 35 | 9 | 21.0 | 1,166 |
| March | 123 | 23 | 57.4 | 3,530 |
| April | 260 | 83 | 208 | 12,380 |
| May | 210 | 109 | 152 | 9,346 |
| June | 181 | 0 | a 150 | 8,926 |
| July | 7 | 0 | a 150 | 9,223 |
| August | 158 | 3 | a 150 | 9,223 |
| September | 202 | 35 | 144 | 8,569 |
| October | 196 | 2 | 96.6 | 5,940 |
| November | 71 | 8 | 27.0 | 1,607 |
| The period | | | | 71,430 |

a Estimated. Flood water used for irrigation. Beginning with March 6 Holt heading was used to divert water in No. 5 main canal, but its capacity was not sufficient until April 16.

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*Estimated monthly discharge of New Holt or No. 7 canal near Calexico, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| May | | | 18 | 1,10 |
| June | | | 33 | 1,96 |
| July | | | 33 | 2,02 |
| August | | | 33 | 2,02 |
| September | | | 33 | 1,96 |
| October | | | 33 | 2,02 |
| November | | | 33 | 1,96 |
| The period | | | | 13,04 |

NOTE.—The station record is of no value because most of the water used was obtained from flooded basins to the east. The mean discharge for the entire district covered by the canal was estimated in the field at 33 second-feet.

*Discharge measurements of Hemlock canal near Calexico, Cal., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec.-ft.* | | | *Feet.* | *Sec.-ft.* |
| January 4 | W. V. Hardy | 0.87 | 2.0 | June 26 | R. R. McCoslin | 1.96 | 21.0 |
| January 12 | do | 0.88 | 2.2 | July 3 | do | 1.23 | 7. |
| January 19 | do | 1.41 | 9.5 | July 10 | do | 1.73 | 17.0 |
| January 26 | do | 0.84 | 1.9 | July 17 | do | 1.69 | 15. |
| February 2 | do | 1.25 | 7.4 | July 24 | do | 0.75 | 0. |
| February 9 | do | 1.64 | 16.4 | July 31 | do | 1.23 | 7.9 |
| February 17 | R. R. McCoslin | 1.59 | 12.5 | August 7 | do | 1.43 | 12.7 |
| February 24 | do | 1.79 | 17.2 | August 14 | do | 1.59 | 17.4 |
| March 13 | do | 1.20 | 8.7 | August 21 | do | 1.23 | 9. |
| March 20 | do | 1.45 | 13.2 | August 28 | do | 1.12 | 7.3 |
| March 27 | do | 1.73 | 23.0 | September 4 | W. V. Hardy | 0.97 | 4.4 |
| April 3 | do | 1.85 | 20.0 | September 11 | do | 1.42 | 13. |
| April 10 | do | 1.42 | 12.7 | September 25 | do | 0.82 | 2.1 |
| April 17 | do | 2.45 | 36.0 | October 2 | do | 1.11 | 7. |
| April 24 | do | 0.70 | 1.6 | October 10 | do | 1.30 | 8. |
| May 1 | do | 1.10 | 6.4 | October 17 | do | 1.12 | 8.9 |
| May 8 | do | 2.04 | 20.4 | October 23 | do | 1.20 | 8.4 |
| May 15 | do | 1.94 | 18.6 | October 30 | do | 1.04 | 5. |
| May 22 | do | 1.75 | 14.5 | November 6 | do | 0.90 | 4.0 |
| May 29 | do | 1.54 | 12.1 | November 13 | do | 1.00 | 6.4 |
| June 5 | do | 1.81 | 16.9 | November 20 | do | 0.70 | 2.0 |
| June 12 | do | 0.78 | 2.1 | November 29 | do | 0.89 | 3.1 |
| June 18 | do | 1.7 | 13.2 | | | | |

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*Mean daily gage height, in feet, of Hemlock canal near Calexico, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 1.0 | 0.9 | (1.8) | 1.1 | 1.55 | 1.6 | 1.2 | 1.15 | 1.0 | 1.1 | 1.0 |
| 2 | .9 | 1.25 | .9 | 1.9 | 1.05 | 1.55 | 1.5 | 1.2 | 1.1 | 1.1 | 1.15 | 1.0 |
| 3 | .95 | 1.3 | .9 | 1.85 | 1.2 | 1.6 | 1.25 | 1.2 | .9 | 1.1 | 1.25 | 2.0 |
| 4 | 1.0 | 1.3 | .9 | 1.8 | 1.35 | 1.7 | 1.2 | 1.3 | .95 | 1.15 | 1.1 | 1.5 |
| 5 | 1.05 | 1.1 | 1.05 | 2.0 | 1.7 | 1.8 | 1.2 | 1.3 | 1.2 | 1.2 | .95 | 1.5 |
| 6 | 1.15 | .8 | 1.25 | (2.0) | 1.95 | 1.9 | 1.2 | 1.4 | 1.35 | 1.3 | .9 | 1.7 |
| 7 | 1.3 | .8 | 1.3 | (1.9) | 2.0 | 1.95 | 1.55 | 1.45 | 1.35 | 1.45 | .9 | 1.65 |
| 8 | 1.4 | 1.0 | 1.3 | (1.6) | 2.1 | 2.05 | 1.75 | 1.4 | 1.35 | 1.45 | .9 | 1.6 |
| 9 | 1.0 | 1.65 | 1.5 | (1.5) | 2.1 | 2.1 | 1.75 | 1.4 | 1.35 | 1.4 | .95 | 1.55 |
| 10 | .75 | 1.65 | 1.25 | (1.4) | 2.1 | 2.15 | 1.75 | 1.4 | 1.4 | 1.35 | 1.0 | 1.6 |
| 11 | .75 | 1.55 | 1.25 | (1.6) | 2.1 | 2.15 | 1.75 | 1.5 | 1.4 | 1.4 | 1.05 | ..... |
| 12 | .75 | 1.35 | 1.3 | (1.7) | 2.1 | .8 | 1.75 | 1.55 | 1.45 | 1.35 | 1.1 | ..... |
| 13 | .75 | 1.1 | 1.2 | 1.9 | 2.1 | .8 | 1.7 | 1.55 | 1.5 | 1.5 | 1.05 | ..... |
| 14 | .75 | 1.15 | 1.05 | 1.8 | 2.1 | .9 | 1.7 | 1.6 | 1.55 | 1.0 | .95 | ..... |
| 15 | .75 | 1.4 | .95 | 2.0 | 1.95 | .9 | 1.7 | 1.4 | 1.55 | 1.15 | .75 | ..... |
| 16 | .75 | 1.8 | .9 | (2.2) | 2.0 | .9 | 1.7 | 1.25 | 1.55 | 1.25 | .8 | ..... |
| 17 | .75 | 1.6 | 1.05 | 2.45 | 1.95 | 1.4 | 1.7 | 1.2 | 1.55 | 1.1 | .8 | ..... |
| 18 | 1.0 | 1.75 | 1.0 | 2.5 | 1.85 | 1.7 | 1.8 | 1.2 | 1.3 | 1.0 | .85 | ..... |
| 19 | 1.4 | 1.75 | 1.05 | 2.2 | 1.85 | 1.65 | 1.85 | 1.2 | .95 | 1.05 | .8 | ..... |
| 20 | 1.55 | 1.65 | 1.45 | 2.45 | 1.8 | 1.6 | 1.45 | 1.2 | 1.0 | 1.1 | .7 | ..... |
| 21 | (1.4) | 1.5 | 1.5 | 2.35 | 1.75 | 1.55 | 1.0 | 1.25 | 1.05 | 1.0 | .8 | ..... |
| 22 | (1.3) | 1.45 | 1.4 | 2.2 | 1.75 | 1.5 | 1.0 | 1.2 | 1.0 | 1.0 | .9 | ..... |
| 23 | (1.2) | 1.55 | 1.25 | (2.0) | 1.7 | 1.5 | 1.0 | 1.2 | 1.0 | 1.2 | .85 | ..... |
| 24 | (1.0) | 1.8 | 1.3 | 1.45 | 1.75 | 1.75 | .75 | 1.2 | .9 | 1.15 | .75 | ..... |
| 25 | (.9) | 1.65 | 1.55 | 1.45 | (1.7) | 1.95 | .75 | 1.2 | .95 | 1.05 | .75 | ..... |
| 26 | .85 | 1.05 | 1.55 | 1.2 | (1.65) | 1.85 | .75 | 1.2 | 1.0 | 1.05 | .75 | ..... |
| 27 | 1.0 | .9 | 1.75 | 1.1 | (1.6) | 1.8 | .75 | 1.2 | 1.0 | 1.1 | .75 | ..... |
| 28 | 1.0 | .9 | 1.55 | 1.1 | (1.55) | 1.8 | 1.05 | 1.1 | .9 | 1.1 | .85 | ..... |
| 29 | .7 | ..... | 1.15 | 1.1 | 1.5 | 1.75 | 1.25 | 1.1 | .95 | 1.2 | .95 | ..... |
| 30 | .6 | ..... | 1.5 | 1.1 | 1.55 | 1.75 | 1.25 | 1.05 | .95 | .9 | 1.3 | ..... |
| 31 | .55 | ..... | 1.9 | ..... | 1.6 | ..... | 1.25 | 1.0 | ..... | .85 | ..... | ..... |

NOTE.—Gage heights in parentheses are estimated.

*Estimated monthly discharge of Hemlock canal near Calexico, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 12.0 | 0.4 | 4.3 | 264 |
| February | 17.4 | 2.0 | 10.0 | 555 |
| March | 23.0 | 3.3 | 10.7 | 658 |
| April | 39.0 | 6.6 | 19.3 | 1,149 |
| May | 21.6 | 5.4 | 15.7 | 965 |
| June | 25.2 | 1.8 | 14.1 | 839 |
| July | 18.4 | 0.8 | 10.9 | 670 |
| August | 17.5 | 5.2 | 10.4 | 639 |
| September | 14.0 | 3.3 | 8.1 | 482 |
| October | 12.6 | 2.4 | 7.5 | 461 |
| November | 9.6 | 1.4 | 4.6 | 274 |
| The period | | | | 6,955 |

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*Discharge measurements of New River near Calexico, Cal., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec.-ft.* | | | *Feet.* | *Sec.-ft.* |
| January 5 | W. V. Hardy | 2.00 | 12 | May 23 | R. R. McCoslin | 9.24 | 3,0[illegible] |
| January 13 | do | 3.20 | 82 | May 30 | do | 9.38 | 3,4[illegible] |
| January 20 | do | 3.30 | 99 | June 6 | do | 9.77 | 3,8[illegible] |
| January 27 | do | 5.20 | 323 | June 13 | do | 10.85 | 4,9[illegible] |
| February 3 | do | 4.00 | 126 | June 20 | do | 11.81 | 5,9[illegible] |
| February 10 | do | 5.70 | 451 | June 27 | do | 12.70 | 10,8[illegible] |
| February 18 | do | 6.90 | 986 | July 5 | do | 13.21 | 11,9[illegible] |
| February 23 | R. R. McCoslin | 7.14 | 1,063 | July 12 | do | 13.34 | 13,6[illegible] |
| March 2 | do | 7.48 | 1,461 | July 18 | Hardy and McCoslin | 13.11 | 13,2[illegible] |
| March 9 | do | 7.90 | 1,702 | July 25 | do | 12.42 | 10,0[illegible] |
| March 16 | do | 7.77 | 1,648 | August 1 | R. R. McCoslin | 11.38 | 8,2[illegible] |
| March 23 | do | 6.74 | 1,159 | August 8 | McCosland and Hardy | 10.72 | 6,5[illegible] |
| March 29 | do | 8.93 | 2,916 | August 15 | do | 10.90 | 6,9[illegible] |
| April 6 | do | 6.95 | 1,307 | August 22 | do | 10.22 | 5,5[illegible] |
| April 12 | do | 6.50 | 949 | August 29 | M. V. Hardy | 9.42 | 4,3[illegible] |
| April 18 | do | 6.80 | 1,149 | September 5 | Hardy and McCoslin | 9.31 | 3,8[illegible] |
| April 25 | do | 8.71 | 3,052 | September 12 | do | 7.52 | 1,8[illegible] |
| May 2 | do | 8.47 | 2,417 | | | | |
| May 9 | do | 8.80 | 2,890 | | | | |
| May 16 | do | 9.19 | 3,237 | | | | |

*Discharge measurements of Alamo Channel near Rockwood, Cal., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec.-ft.* | | | *Feet.* | *Sec.-ft.* |
| January 7 | W. V. Hardy | ..... | 49 | May 17 | R. R. McCoslin | 6.00 | 990 |
| January 14 | do | ..... | 205 | May 24 | W. V. Hardy | 6.37 | 1,562 |
| January 21 | do | ..... | 77 | May 31 | do | 5.92 | 1,692 |
| January 28 | do | ..... | 112 | June 7 | do | 6.28 | 2,110 |
| February 4 | do | ..... | 151 | June 14 | do | 6.85 | 3,644 |
| February 11 | do | ..... | 61 | June 21 | do | ..... | 5,348 |
| February 20 | do | ..... | 530 | June 28 | do | 9.60 | 3,253 |
| February 25 | do | ..... | 94 | July 6 | do | 9.00 | 4,234 |
| March 3 | do | 7.48 | 387 | July 13 | do | 9.50 | 3,932 |
| March 11 | do | 6.80 | 1,088 | July 19 | do | ..... | 3,501 |
| March 17 | do | 7.15 | 1,379 | July 26 | do | ..... | 3,104 |
| March 25 | do | 10.00 | 1,806 | August 2 | do | 8.80 | 3,551 |
| March 30 | do | 9.50 | 1,443 | August 9 | do | 8.60 | 2,815 |
| April 8 | do | 6.20 | 635 | August 16 | do | 8.50 | 2,874 |
| April 13 | do | 6.00 | 692 | August 23 | do | 9.80 | 2,439 |
| April 19 | R. R. McCoslin | 6.00 | 772 | August 30 | do | 9.93 | 2,509 |
| April 26 | do | (a) | a 632 | September 6 | Hardy and McCoslin | 9.95 | 2,115 |
| May 3 | do | ..... | 1,044 | September 13 | do | 10.45 | 3,500 |
| May 10 | do | ..... | 1,770 | | | | |

a Gage washed out.

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*Discharge measurements of Alamitos canal, Calexico, Cal., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec.-ft.* | | | *Feet.* | *Sec.-ft.* |
| January 3 | W. V. Hardy | 1.48 | 30 | June 12 | R. R. McCoslin | 1.32 | 37 |
| January 11 | do | 1.54 | 39 | June 18 | W. V. Hardy | 1.30 | 30 |
| January 18 | do | 1.11 | 15.1 | June 26 | R. R. McCoslin | 1.35 | 36 |
| January 26 | do | 1.05 | 12.9 | July 5 | do | 1.33 | 34 |
| February 2 | do | 1.06 | 13.6 | July 10 | do | 1.34 | 33 |
| February 9 | do | 0.52 | 1.0 | July 17 | do | 1.35 | 34 |
| February 17 | R. R. McCoslin | 1.05 | 16.8 | July 24 | do | 1.34 | 33 |
| February 24 | do | 1.00 | 15.7 | July 31 | do | 1.34 | 33 |
| March 1 | do | 0.82 | 9.1 | Aug. 7 | do | 1.12 | 22 |
| March 8 | do | | 0 | August 14 | do | 1.12 | 22 |
| March 15 | do | | 0 | August 21 | do | 1.17 | 24 |
| March 22 | do | | 0 | August 28 | do | 1.27 | 31 |
| March 29 | do | 1.20 | 24 | September 4 | do | 1.34 | 39 |
| April 5 | do | 1.53 | 44 | September 11 | W. V. Hardy | 1.42 | 43 |
| April 11 | do | 1.63 | 50 | September 25 | do | 1.23 | 36 |
| April 17 | do | 1.67 | 57 | October 9 | do | 1.30 | 40 |
| April 24 | do | 1.39 | 40 | October 16 | do | 1.32 | 45 |
| May 1 | do | 1.10 | 26 | October 23 | do | 1.27 | 38 |
| May 8 | do | 1.15 | 28 | November 13 | do | | 0 |
| May 15 | do | 1.41 | 39 | November 18 | do | | 0 |
| May 22 | do | 1.34 | 35 | November 30 | do | 0 42 | 5.4 |
| May 29 | do | 1.37 | 36 | October 30 | do | 0.90 | 18.3 |
| June 5 | do | 1.35 | 36 | November 6 | do | | 0 |

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*Mean daily height in feet, of Alamitos canal near Calexico, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1.2 | 0.8 | 1.35 | 1.1 | 1.35 | 1.3 | 1.05 | 1.4 | 1.1 | 0.45 | 0.2 |
| 2 | 1.5 | 1.1 | .8 | 1.5 | 1.1 | 1.35 | 1.3 | 9 | 1.4 | 1.25 | .45 | .25 |
| 3 | 1.5 | 1.25 | .6 | 1.6 | 1.1 | 1.35 | 1.35 | 1.05 | 1.35 | 1.15 | .2 | .25 |
| 4 | 1.45 | 1.1 | .4 | 1.55 | 1.1 | 1.35 | 1.35 | 1.1 | 1.35 | 1.3 | .1 | .2 |
| 5 | 1.45 | .95 | .35 | 1.5 | 1.1 | 1.35 | 1.35 | 1.1 | 1.3 | 1.3 | .0 | .2 |
| 6 | 1.4 | .95 | .35 | 1.55 | 1.1 | 1.35 | 1.35 | 1.1 | 1.35 | 1.3 | .15 | .2 |
| 7 | 1.45 | .95 | .3 | 1.6 | 1.1 | 1.35 | 1.35 | 1.1 | 1.45 | 1.25 | .25 | .2 |
| 8 | 1.5 | .9 | .1 | 1.6 | 1.15 | 1.35 | 1.35 | 1.1 | 1.45 | 1.25 | .3 | .2 |
| 9 | 1.6 | .7 | .1 | 1.6 | 1.2 | 1.3 | 1.35 | 1.15 | 1.4 | 1.25 | .3 | .2 |
| 10 | 1.6 | .5 | .1 | 1.65 | 1.25 | 1.35 | 1.35 | 1.15 | 1.4 | 1.25 | .3 | .2 |
| 11 | 1.6 | .5 | .1 | 1.65 | 1.3 | 1.3 | 1.35 | 1.15 | 1.4 | 1.25 | .25 | .2 |
| 12 | 1.6 | .5 | .1 | 1.65 | 1.4 | 1.3 | 1.35 | 1.15 | 1.45 | 1.25 | .3 | .25 |
| 13 | 1.6 | .5 | .1 | 1.65 | 1.4 | 1.3 | 1.35 | 1.15 | 1.5 | 1.25 | .3 | ..... |
| 14 | 1.7 | .5 | .1 | 1.65 | 1.4 | 1.35 | 1.35 | 1.1 | 1.45 | 1.3 | .25 | ..... |
| 15 | 1.45 | .55 | .0 | 1.65 | 1.4 | 1.35 | 1.35 | 1.1 | 1.4 | 1.3 | .3 | ..... |
| 16 | 1.5 | .65 | .0 | 1.65 | 1.3 | 1.35 | 1.35 | 1.1 | 1.4 | 1.35 | .3 | ..... |
| 17 | 1.15 | 1.05 | .0 | 1.65 | 1.2 | 1.3 | 1.35 | 1.1 | 1.4 | 1.35 | .25 | ..... |
| 18 | 1.1 | 1.05 | .0 | 1.7 | 1.2 | 1.3 | 1.35 | 1.1 | 1.4 | 1.35 | .2 | ..... |
| 19 | 1.1 | 1.05 | .0 | 1.75 | 1.2 | 1.3 | 1.35 | 1.15 | 1.35 | 1.25 | .2 | ..... |
| 20 | 1.1 | 1.05 | .0 | 1.35 | 1.25 | 1.3 | 1.35 | 1.2 | 1.4 | 1.2 | .2 | ..... |
| 21 | 1.05 | 1.05 | .0 | 1.4 | 1.35 | 1.3 | 1.35 | 1.2 | 1.45 | 1.2 | .15 | ..... |
| 22 | 1.1 | 1.05 | .0 | 1.55 | 1.35 | 1.3 | 1.35 | 1.15 | 1.45 | 1.15 | .15 | ..... |
| 23 | 1.1 | 1.0 | .15 | 1.45 | 1.35 | 1.3 | 1.35 | 1.2 | 1.4 | 1.25 | .15 | ..... |
| 24 | 1.1 | 1.0 | .65 | 1.4 | 1.35 | 1.3 | 1.35 | 1.25 | 1.2 | 1.25 | .2 | ..... |
| 25 | 1.0 | 1.05 | .7 | 1.4 | 1.35 | 1.35 | 1.35 | 1.25 | 1.25 | 1.2 | .25 | ..... |
| 26 | 1.05 | 1.1 | .7 | 1.4 | 1.35 | 1.35 | 1.35 | 1.25 | 1.25 | 1.2 | .25 | ..... |
| 27 | 1.15 | .8 | .85 | 1.4 | 1.35 | 1.35 | 1.35 | 1.3 | 1.2 | 1.15 | .35 | ..... |
| 28 | 1.2 | .75 | .9 | 1.25 | 1.35 | 1.35 | 1.35 | 1.3 | 1.1 | 1.15 | .4 | ..... |
| 29 | 1.2 | ..... | 1.3 | 1.15 | 1.35 | 1.35 | 1.35 | 1.3 | 1.15 | 1.15 | .35 | ..... |
| 30 | 1.2 | ..... | 1.4 | 1.15 | 1.35 | 1.3 | 1.35 | 1.25 | 1.1 | .9 | .25 | ..... |
| 31 | 1.25 | ..... | 1.3 | ..... | 1.35 | ..... | 1.35 | 1.3 | ..... | .8 | ..... | ..... |

*Estimated monthly discharge of Alamitos canal near Calexico, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 50 | 11 | 26.6 | 1,636 |
| February | 23 | .5 | 11.4 | 633 |
| March | 36 | 0 | 4.9 | 301 |
| April | 65 | 28 | 45.6 | 2,714 |
| May | 40 | 25 | 31.8 | 1,955 |
| June | 38 | 30 | 34.4 | 2,047 |
| July | 35 | 32 | 33.9 | 2,084 |
| August | 34 | 11 | 23.9 | 1,470 |
| September | 49 | 28 | 40.8 | 2,428 |
| October | 47 | 18 | 35.8 | 2,201 |
| November | 6 | 0 | 2.7 | 161 |
| The period | ..... | ..... | ..... | 17,630 |

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*Discharge measurements of Main canal near Calexico, Cal., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec. ft.* | | | *Feet.* | *Sec. ft.* |
| January 3 | W. V. Hardy | 3.90 | 439 | June 12 | R. R. McCoslin | 4.17 | 565 |
| January 11 | do | 4.20 | 524 | June 18 | do | 4.14 | 540 |
| January 18 | do | 4.50 | 567 | June 26 | do | 4.23 | 571 |
| January 26 | do | 4.20 | 510 | July 3 | do | 4.25 | 562 |
| February 2 | do | 4.18 | 507 | July 10 | do | 4.38 | 567 |
| February 15 | do | 4.09 | 485 | July 17 | do | 4.36 | 582 |
| February 17 | R. R. McCoslin | 4.15 | 472 | July 24 | do | 4.32 | 583 |
| February 23 | do | 3.95 | 447 | July 31 | do | 4.23 | 580 |
| March 1 | do | 4.49 | 595 | August 7 | do | 4.29 | 556 |
| March 8 | do | | 0 | August 14 | do | 4.33 | 562 |
| March 15 | do | | 0 | August 21 | do | 4.33 | 540 |
| March 22 | do | 3.52 | 410 | August 28 | do | 4.29 | 536 |
| March 29 | do | 4.79 | 651 | September 4 | do | 4.30 | 558 |
| April 5 | do | 4.84 | 675 | September 11 | W. V. Hardy | | 0 |
| April 11 | do | 4.98 | 729 | September 25 | do | 4.27 | 551 |
| April 17 | do | 5.04 | 735 | October 2 | do | | 0 |
| April 24 | do | 4.91 | 725 | October 9 | do | 4.29 | 559 |
| May 1 | do | 4.47 | 648 | October 16 | do | 4.30 | 546 |
| May 8 | do | 4.42 | 623 | November 3 | do | 2.90 | 298 |
| May 15 | do | 4.34 | 586 | November 6 | do | 3.60 | 380 |
| May 22 | do | 4.24 | 562 | November 13 | do | 3.60 | 380 |
| May 29 | do | 4.32 | 595 | November 18 | do | 3.55 | 378 |
| June 5 | do | 4.19 | 566 | November 30 | do | 3.50 | 376 |

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*Mean daily gage height, in feet, of Main canal near Calexico, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.9 | 4.05 | 4.5 | 4.7 | 4.45 | 4.2 | 4.25 | 4.2 | 4.3 | (a) | 2.3 | 3.4 |
| 2 | 3.95 | 4.2 | 4.45 | 4.85 | 4.4 | 4.2 | 4.25 | 4.2 | 4.3 | (a) | 2.9 | 3.45 |
| 3 | 3.9 | 4.25 | 4.05 | 4.95 | 4.4 | 4.2 | 4.25 | 4.2 | 4.3 | (a) | 3.22 | 3.75 |
| 4 | 3.85 | 4.15 | (a) | 4.9 | 4.4 | 4.2 | 4.25 | 4.25 | 4.3 | (a) | 3.55 | 3.5 |
| 5 | 3.85 | 3.95 | (a) | 4.85 | 4.45 | 4.2 | 4.25 | 4.25 | 4.3 | 3.95 | 3.45 | 3.9 |
| 6 | 3.75 | 3.8 | (a) | 4.9 | 4.4 | 4.2 | 4.25 | 4.25 | 4.3 | 4.2 | (3.55) | 3.95 |
| 7 | 3.7 | 3.8 | (a) | 4.95 | 4.4 | 4.2 | 4.3 | 4.3 | (a) | 4.25 | (3.6) | 3.95 |
| 8 | 3.75 | 3.8 | (a) | 4.95 | 4.45 | 4.2 | 4.35 | 4.3 | (a) | 4.2 | (3.6) | 3.95 |
| 9 | 3.95 | 3.85 | (a) | 5.0 | 4.45 | 4.2 | 4.35 | 4.3 | (a) | 4.3 | (3.6) | 3.95 |
| 10 | 4.2 | 3.85 | (a) | 5.0 | 4.4 | 4.2 | 4.35 | 4.3 | (a) | 4.3 | (3.6) | 3.6 |
| 11 | 4.2 | 3.85 | (a) | 5.0 | 4.4 | 4.2 | 4.35 | 4.35 | (a) | 4.3 | 3.6 | ..... |
| 12 | 4.4 | 3.85 | (a) | 5.0 | 4.45 | 4.2 | 4.35 | 4.35 | .5 | 4.3 | 3.6 | ..... |
| 13 | 4.55 | 3.8 | (a) | 5.0 | 4.45 | 4.2 | 4.35 | 4.35 | 2.0 | 4.3 | 3.6 | ..... |
| 14 | 4.4 | 3.95 | (a) | 5.0 | 4.4 | 4.25 | 4.35 | 4.35 | 2.5 | 4.3 | 3.6 | ..... |
| 15 | 4.3 | 4.1 | (a) | 5.05 | 4.35 | 4.2 | 4.35 | 4.35 | 2.95 | 4.3 | (3.6) | ..... |
| 16 | 4.35 | 4.2 | (a) | 5.05 | 4.3 | 4.2 | 4.35 | 4.35 | 3.1 | 4.35 | (3.6) | ..... |
| 17 | 4.4 | 4.1 | (a) | 5.05 | 4.3 | 4.25 | 4.35 | 4.35 | 3.15 | 4.35 | (3.6) | ..... |
| 18 | (4.5) | 4.05 | (a) | 5.1 | 4.3 | 4.2 | 4.35 | 4.35 | 3.15 | 4.35 | 3.6 | ..... |
| 19 | 4.5 | 4.05 | (a) | 5.1 | 4.3 | 4.2 | 4.35 | 4.35 | 3.5 | 4.3 | 3.55 | ..... |
| 20 | 4.55 | 4.0 | (1.5) | 5.0 | 4.3 | 4.2 | 4.35 | 4.35 | 3.9 | 4.3 | 3.4 | ..... |
| 21 | 4.5 | 3.9 | 3.35 | 5.0 | 4.3 | 4.2 | 4.35 | 4.35 | 4.05 | 4.3 | 3.4 | ..... |
| 22 | 4.55 | 3.9 | 3.5 | 5.0 | 4.25 | 4.25 | 4.3 | 4.3 | 4.2 | 4.3 | 3.4 | ..... |
| 23 | 4.5 | 3.95 | 3.8 | 4.9 | 4.3 | 4.3 | 4.3 | 4.3 | 4.35 | (a) | 3.2 | ..... |
| 24 | 4.35 | 4.1 | 4.15 | 4.95 | 4.3 | 4.3 | 4.3 | 4.3 | 4.35 | (a) | 3.05 | ..... |
| 25 | 4.25 | 4.3 | (4.5) | 4.9 | 4.3 | 4.25 | 4.35 | 4.3 | 4.3 | (a) | 3.05 | ..... |
| 26 | 4.2 | 4.4 | (4.8) | 4.9 | 4.3 | 4.25 | 4.3 | 4.3 | 4.25 | (a) | 3.05 | ..... |
| 27 | 4.05 | 4.5 | (4.8) | 4.9 | 4.3 | 4.25 | 4.3 | 4.3 | 4.25 | .1 | 3.05 | ..... |
| 28 | 3.95 | 4.5 | (4.8) | 4.9 | 4.3 | 4.25 | 4.8 | 4.3 | 4.25 | .8 | 3.05 | ..... |
| 29 | 3.9 | ..... | (4.8) | 4.8 | 4.3 | 4.25 | 4.3 | 4.3 | 4.25 | .85 | 3.4 | ..... |
| 30 | 3.85 | ..... | 4.8 | 4.6 | 4.2 | 4.25 | 4.3 | 4.3 | 3.1 | 1.7 | 3.45 | ..... |
| 31 | 3.85 | ..... | 4.7 | ..... | 4.2 | ..... | 4.25 | 4.3 | ..... | 1.7 | ..... | ..... |

a No flow.

NOTE.—Gage heights in parentheses are estimated.

*Estimated monthly discharge of Main canal near Calexico, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 600 | 398 | 500 | 30,740 |
| February | 595 | 416 | 470 | 26,100 |
| March | 672 | 0 | 261 | 16,050 |
| April | 752 | 634 | 719 | 42,780 |
| May | 648 | 566 | 598 | 36,770 |
| June | 582 | 548 | 570 | 33,920 |
| July | 593 | 556 | 575 | 35,360 |
| August | 568 | 536 | 553 | 34,000 |
| September | 570 | 0 | 369 | 21,960 |
| October | 561 | 0 | 328 | 20,170 |
| November | 390 | 220 | 351 | 20,890 |
| The period | ..... | ..... | ..... | 318,700 |

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*Discharge measurements of Boundary canal near Calexico, Cal., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec.-ft.* | | | *Feet.* | *Sec.-ft.* |
| January 3 | W. V. Hardy | 0.80 | 6.4 | June 12 | R. R. McCoslin | 0.35 | 0.22 |
| January 11 | do | .98 | 8.6 | June 18 | do | 1.00 | 11.0 |
| January 18 | do | 1.00 | 8.9 | June 26 | do | .91 | 7.5 |
| January 25 | do | ..... | 7.8 | July 3 | do | .93 | 6.4 |
| February 2 | do | .99 | 9.1 | July 10 | do | .78 | 4.8 |
| February 9 | do | .95 | 8.3 | July 17 | do | .77 | 4.2 |
| February 17 | R. R. McCoslin | .79 | 5.3 | July 24 | do | .96 | 6.6 |
| February 23 | do | .98 | 8.3 | July 31 | do | .87 | 5.3 |
| March 1 | do | 1.00 | 10.0 | August 7 | do | .83 | 6.2 |
| March 5 | do | ..... | 0 | August 14 | do | .78 | 5.7 |
| March 8 | do | ..... | 0 | August 21 | do | .79 | 5.7 |
| March 22 | do | .88 | 7.8 | August 28 | do | .79 | 4.8 |
| March 29 | do | .80 | 6.2 | September 4 | do | .80 | 3.8 |
| April 5 | do | .85 | 8.5 | September 11 | do | ..... | 0 |
| April 11 | do | .99 | 10.4 | October 2 | W. V. Hardy | ..... | 0 |
| April 17 | do | 1.00 | 11.7 | October 6 | do | .90 | 8.4 |
| April 24 | do | 1.08 | 13.0 | October 9 | do | .87 | 5.3 |
| May 1 | do | .83 | 6.1 | October 16 | do | .80 | 5.0 |
| May 8 | do | .83 | 7.5 | October 18 | do | .25 | 0 |
| May 15 | do | .74 | 6.1 | October 30 | do | .85 | 8.0 |
| May 22 | do | .71 | 5.1 | November 13 | do | .90 | 8.4 |
| May 29 | do | .85 | 8.0 | November 18 | do | .95 | 7.0 |
| June 5 | do | .90 | 8.4 | November 30 | do | 1.03 | 12.7 |

*Estimated monthly discharge of Boundary canal near Calexico, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 8.9 | 6.0 | 8.1 | 498 |
| February | 9.8 | 5.1 | 7.8 | 433 |
| March | 10.0 | 0 | 3.6 | 221 |
| April | 13.0 | 7.0 | 10.2 | 607 |
| May | 8.0 | 5.1 | 6.5 | 400 |
| June | 11.0 | .2 | 7.9 | 471 |
| July | 6.8 | 4.2 | 5.4 | 332 |
| August | 6.2 | 4.4 | 5.6 | 344 |
| September | 6.0 | 0 | 3.8 | 227 |
| October | 8.0 | 0 | 4.4 | 271 |
| November | 12.7 | 7.0 | 9.0 | 536 |
| The period | ..... | ..... | ..... | 4,340 |

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*Discharge measurements of Wisteria canal near Calexico, Cal., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec.-ft.* | | | *Feet.* | *Sec.-ft.* |
| January 5 | W. V. Hardy | 1.12 | 3.0 | June 13 | R. R. McCoslin | 0.35 | 10.6 |
| January 11 | do | .15 | 0 | June 19 | W. V. Hardy | .57 | 13.5 |
| January 18 | do | .52 | 7.7 | June 26 | R. R. McCoslin | .38 | 10.6 |
| January 25 | do | .92 | 22 | July 5 | do | .30 | 9.4 |
| February 1 | do | .80 | 16.5 | July 11 | do | .96 | 32 |
| February 10 | do | ..... | 0 | July 18 | do | .66 | 17.8 |
| February 18 | do | ..... | 0 | July 25 | W. V. Hardy | ..... | 0 |
| February 25 | R. R. McCoslin | ..... | 0 | August 1 | do | .33 | 7.8 |
| March 1 | do | ..... | 0 | August 8 | do | ..... | 0 |
| March 15 | do | ..... | 0 | August 15 | R. R. McCoslin | ..... | 0 |
| March 23 | do | ..... | 0 | August 22 | W. V. Hardy | ..... | 0 |
| March 29 | do | .90 | 26 | August 29 | R. R. McCoslin | ..... | 0 |
| April 6 | do | 1.65 | 64 | September 5 | W. V. Hardy | ..... | 0 |
| April 12 | do | 1.29 | 47 | September 12 | do | ..... | 0 |
| April 18 | do | 1.00 | 33 | September 26 | do | ..... | 0 |
| April 25 | do | .95 | 32 | October 3 | do | ..... | 0 |
| May 2 | do | .50 | 13.1 | October 11 | do | ..... | 0 |
| May 9 | do | .85 | 26 | October 18 | do | .60 | 12.8 |
| May 16 | do | .43 | 12.2 | October 31 | do | .60 | 14 |
| May 23 | do | .63 | 17.1 | November 7 | do | .40 | 12 |
| May 30 | do | .42 | 12.1 | November 14 | do | ..... | 0 |
| June 6 | do | .38 | 11.9 | November 21 | do | .15 | 0 |

[a] Estimated.

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*Daily gage height, in feet, of Wisteria canal near Calexico, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.95 | 0.8 | 0.25 | 1.5 | 0.3 | 0.4 | 0.3 | 0.35 | 0 | 0.0 | 0.6 |
| 2 | .9 | .8 | .2 | 1.2 | .4 | .4 | .3 | .05 | 0 | .0 | .6 |
| 3 | 1.15 | .8 | .2 | 1.7 | .4 | .4 | .3 | .05 | 0 | .0 | .6 |
| 4 | 1.1 | 1.0 | .2 | 1.8 | .4 | .4 | .3 | .05 | 0 | .0 | .6 |
| 5 | 1.1 | .55 | .2 | 1.6 | .7 | .4 | .3 | .0 | 0 | .0 | .0 |
| 6 | 1.1 | .3 | .2 | 1.65 | .7 | .4 | .3 | .0 | 0 | .0 | .4 |
| 7 | 1.25 | .0 | .2 | 1.7 | .8 | .4 | .3 | .0 | 0 | .0 | .4 |
| 8 | 1.3 | .0 | .15 | 1.6 | .8 | .4 | .3 | .0 | 0 | .0 | .75 |
| 9 | .95 | .0 | .15 | 1.5 | .8 | .4 | .3 | .0 | 0 | .0 | .75 |
| 10 | .95 | .0 | .15 | 1.45 | .8 | .3 | .3 | .0 | 0 | .0 | .0 |
| 11 | .15 | .0 | .15 | 1.35 | .5 | .3 | .95 | .0 | 0 | .0 | .0 |
| 12 | .1 | .3 | .35 | 1.15 | .45 | .3 | 1.8 | .0 | 0 | .0 | .0 |
| 13 | .1 | .2 | .35 | 1.1 | .45 | .3 | 1.1 | .0 | 0 | 0.6 | .0 |
| 14 | .0 | .25 | .40 | .95 | .45 | .25 | 1.0 | .0 | 0 | .6 | .0 |
| 15 | .0 | .3 | .35 | 1.0 | .45 | .25 | 1.0 | .0 | 0 | .6 | .5 |
| 16 | .0 | .35 | .3 | 1.0 | .45 | .3 | .9 | .0 | 0 | .6 | .0 |
| 17 | .6 | .25 | .3 | 1.0 | .45 | .0 | .6 | .0 | 0 | .6 | .0 |
| 18 | .2 | .1 | .3 | 1.0 | .45 | .0 | .65 | .0 | 0 | .6 | .0 |
| 19 | .65 | .0 | .5 | .8 | .75 | .4 | .5 | .0 | 0 | .6 | .0 |
| 20 | .8 | .0 | .5 | .7 | .8 | .4 | .5 | .0 | 0 | .6 | .0 |
| 21 | .8 | .0 | .5 | .65 | .8 | .4 | .5 | .0 | 0 | .45 | .15 |
| 22 | .8 | .0 | .5 | 1.0 | .7 | .4 | .45 | .0 | 0 | .45 | .35 |
| 23 | .8 | .0 | .8 | .1 | .6 | .4 | .0 | .0 | 0 | .0 | .35 |
| 24 | .9 | .0 | .8 | .9 | .6 | .4 | .0 | .0 | 0 | .0 | .1 |
| 25 | .9 | .0 | .8 | 1.1 | .7 | .4 | .0 | .0 | 0 | .0 | .0 |
| 26 | 1.0 | .2 | .65 | 1.15 | .7 | .4 | .0 | .0 | 0 | .0 | .0 |
| 27 | 1.1 | .2 | .6 | .9 | .65 | .4 | .0 | .0 | 0 | .05 | .0 |
| 28 | 1.0 | .3 | .8 | .45 | .65 | .3 | .0 | .0 | 0 | .05 | .0 |
| 29 | 1.0 | ..... | .9 | .4 | .4 | .2 | .0 | .0 | 0 | .6 | .0 |
| 30 | 1.0 | ..... | 1.0 | .35 | .4 | .3 | .1 | .0 | 0 | .6 | .0 |
| 31 | .8 | ..... | 1.15 | ..... | .4 | ..... | .35 | .0 | 0 | .6 | ..... |

*Estimated monthly discharge of Wisteria canal near Calexico, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 40 | 0 | 17.9 | 1,100 |
| February | 25 | 0 | 3.8 | 211 |
| March | 32 | 0 | 7.1 | 436 |
| April | 75 | 0 | 39.5 | 2,325 |
| May | 25 | 0 | 16.7 | 1,027 |
| June | 12 | 0 | 9.6 | 572 |
| July | 80 | 0 | 14.2 | 873 |
| August | 11 | 0 | .4 | 25 |
| September | 0 | 0 | .0 | 0 |
| October | 14 | 0 | 5.4 | 332 |
| November | 25 | 0 | 5.6 | 334 |
| The period | ..... | ..... | ..... | 7,261 |

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*Discharge measurements of Tamarack canal near Imperial, Cal., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Date. | Hydrographer. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Sec.-ft.* | | | *Feet.* | *Sec.-ft.* |
| May 25 | W. V. Hardy | | 52 | October 19 | W. V. Hardy | | a 40 |
| June 1 | R. R. McCoslin | 1.70 | 51 | October 26 | do | | a 40 |
| June 8 | W. V. Hardy | 1.80 | 56 | November 2 | do | | a 40 |
| June 14 | do | 1.64 | 43 | November 9 | do | | a 40 |
| June 22 | do | 14.50 | 14 | November 16 | do | | a 40 |
| October 4 | do | | a 40 | November 23 | do | | a 30 |
| October 12 | do | | a 40 | | | | |

a Estimated.

*Daily gage height, in feet, of Tamarack canal near Imperial, Cal., for 1905.*

| Day. | June. | Day. | June. | Day. | June. | Day. | June. | Day | June. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.7 | 7 | 1.8 | 13 | 1.35 | 19 | 1.65 | 25 | 1.2 |
| 2 | 1.68 | 8 | 1.8 | 14 | 1.65 | 20 | 1.75 | 26 | 1.05 |
| 3 | 1.7 | 9 | 1.8 | 15 | 1.65 | 21 | 1.5 | 27 | 1.0 |
| 4 | 1.55 | 10 | 1.9 | 16 | 1.6 | 22 | 1.45 | 28 | .9 |
| 5 | 1.65 | 11 | 1.95 | 17 | 1.65 | 23 | 1.35 | 29 | .9 |
| 6 | 1.75 | 12 | 2.05 | 18 | 1.7 | 24 | 1.2 | 30 | .7 |

*Estimated monthly discharge of Tamarack canal near Imperial, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| June | | | 34.3 | 2,041 |
| July | | | (40) | 2,460 |
| August | | | (40) | 2,460 |
| September | | | (40) | 2,380 |
| October | | | (40) | 2,460 |
| November | | | (40) | 2,380 |
| The period | | | | 14,180 |

NOTE.—Monthly means in parenthesis estimated in the field.

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*Total amount of water (in acre-feet) entering the Imperial Valley through irrigation canals at international boundary, January to November, 1905, inclusive.*

| Canal. | January. | February. | March. | April. | May. | June. |
|---|---|---|---|---|---|---|
| Hemlock | 263 | 555 | 658 | 1,149 | 965 | 839 |
| Boundary | 249 | 216.5 | 110.5 | 303.5 | 200 | 235.5 |
| Wisteria | 1,100 | 211 | 436 | 2,351 | 1,027 | 572 |
| Tamarack | | | | | | 2,041 |
| New Holt, or No. 7 | | | | | 1,107 | 1,964 |
| Main | 30,744 | 26,102 | 16,048 | 42,783 | 36,770 | 33,917 |
| Alamitos | 1,636 | 633 | 301 | 2,714 | 1,955 | 2,047 |
| Holt, or No. 5 Main | 1,525 | 1,162 | 3,530 | 12,377 | 9,340 | 8,926 |
| Alamo Channel | 5,500 | 8,330 | 9,223 | | | |
| Total | 41,017 | 37,209 | 30,306 | 61,677 | 51,370 | 50,541 |

| Canal. | July. | August. | September. | October. | November. | Total. |
|---|---|---|---|---|---|---|
| Hemlock | 670 | 639 | 482 | 461 | 274 | 6,955 |
| Boundary | 166 | 172 | 113.5 | 135.5 | 268 | 2,170 |
| Wisteria | 873 | 25 | 0 | 332 | 334 | 7,261 |
| Tamarack | 2,460 | 2,460 | 2,380 | 2,460 | 2,380 | 14,181 |
| New Holt, or No. 7 | 2,029 | 2,029 | 1,964 | 2,029 | 1,964 | 13,086 |
| Main | 35,355 | 34,003 | 21,957 | 20,168 | 20,886 | 318,733 |
| Alamitos | 2,084 | 1,470 | 2,428 | 2,201 | 161 | 17,630 |
| Holt, or No. 5 Main | 9,223 | 9,223 | 8,569 | 5,940 | 1,607 | 71,428 |
| Alamo Channel | | | | | | 23,053 |
| Total | 52,860 | 50,021 | 37,893 | 33,726 | 27,874 | 474,494 |

*Total amount of water (in acre-feet) entering Imperial Valley, including canals, New River, and Alamo Channel; also amount of waste water discharging into Salton Sea and amount used for irrigation, January to November, 1905, inclusive.*

| Month. | Total discharge Imperial canal at headings below Yuma, Ariz. | Total discharge into Imperial Valley. | Total discharge (waste) into Salton Sea. | Total amount of water used for irrigation. |
|---|---|---|---|---|
| | *Acre-feet.* | *Acre-feet.* | *Acre-feet.* | *Acre-feet.* |
| January | 58,100 | 55,590 | 35,356 | 20,234 |
| February | 227,150 | 92,913 | 77,919 | 14,994 |
| March | 288,990 | 210,896 | 194,548 | 16,348 |
| April | 233,550 | 223,171 | 182,494 | 40,677 |
| May | 335,420 | 321,239 | 287,869 | 33,370 |
| June | 573,020 | 622,911 | 587,370 | 35,541 |
| July | 1,104,620 | 1,037,724 | 978,244 | 50,480 |
| August | 609,030 | 597,751 | 564,946 | 32,805 |
| September | 365,360 | [a] 353,360 | 324,869 | 28,491 |
| October | 468,840 | [a] 456,840 | 435,227 | 21,613 |
| November | 500,000 | [a] 488,000 | 477,977 | 10,023 |
| Total | 4,764,080 | 4,460,395 | 4,155,819 | 304,576 |

[a] Estimated.

Total amount of irrigated land (as per examination made in March and April, 1905)...acres... 79,591
Amount of water used per acre (in acre-feet)..... 3.83

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### LANDS IRRIGATED IN THE IMPERIAL VALLEY.

In April, 1904, an examination was made to determine the amount of lands irrigated in the valley. The gross area under irrigation at that time was 66,741 acres. A second examination was made in September of the same year by W. V. Hardy, of the Reclamation Service, and showed the total area irrigated at that time to be 31,318 acres. Another examination by Mr. Hardy in March and April, 1905, gave a total irrigated area of 79,591 acres.

The examination of area of irrigated land made in March and April, 1905, is used in computing the amount of water per acre used during 1905. It is probable that this area was greatly reduced during the summer, as areas for the raising of hay and grain were not again used after the crops were harvested until the late fall months, when they were again seeded. Large areas of alfalfa and Kaffir corn were necessarily irrigated throughout the year.

### DUTY OF WATER IN THE IMPERIAL VALLEY.

During the fall of 1904 rating flumes were placed on two canals in Imperial Valley for the study of the duty of water. Two types of soil were selected for these investigations, one known as "hard soil" and classified as "Imperial loam" as shown on soil map of Bureau of Soils, United States Department of Agriculture. The other type is known as "soft soil" and classified as "Imperial sandy loam."

The location of the investigation on "Imperial loam" is at the ranch of W. W. McKim, 7 miles east of Imperial, being the west half of sec. 8, T. 15 S., R. 14 E.

The location of the investigation on "Imperial sandy loam" is on lands of the California-Mexico Land Company, 3½ miles east of Mexicala in Mexican territory and directly south of the California-Mexico boundary line in T. 17 S., R. 15 E.

Permanent flumes were constructed at the head of each of these canals and a sufficient number of measurements were made throughout the year for rating them. Self-recording registers were placed at each of these stations, and the mean daily gage height was computed from the register records.

During 1905 the Imperial Valley received a very unusual rainfall. The precipitation at Imperial was 10.06 inches for the year. At Calexico the precipitation was 9.33 inches for the year. The mean annual rainfall will probably not exceed 3 inches in normal years.

#### M'KIM FLUME.

This station was established on September 23, 1904. The amount of land irrigated under this flume is 380 acres. The soil is classified as "Imperial loam." The crops raised during 1905 consisted of 100 acres in barley, which was sown in October, 1904. The crop was only fair and was used for the pasturage of hogs. The balance of the area, 280 acres, had been previously planted to alfalfa, 100 acres having been sown in October, 1902, and 100 acres in October, 1903. This area in alfalfa was in fair condition at the time the station was established. The crop of 1905 was fair and used only for the pasturage of hogs. The supply of water furnished for this area was not enough for thorough irrigation. Water was taken from Alamo channel until March, 1905, and up to this time the supply was sufficient for thorough irrigation. After March, 1905, water was taken from Alamitos canal on account of flood conditions in the Alamo channel which destroyed the levee at point where the diversion was made. The water supply received from the Alamitos canal was not enough for the thorough irrigation of this area and crops suffered considerably from lack of water after March.

The rainfall for this station is taken from the United States Weather Bureau records kept at Imperial, Cal.

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*Monthly duty of water under McKim flume during 1905.*

| Month. | Acre-feet. | | Rainfall in inches. |
|---|---|---|---|
| | Total. | Per acre. | |
| January | 24.6 | 0.06 | 1.50 |
| February | 16.7 | .04 | 6.12 |
| March | 12.3 | .03 | 1.05 |
| April | 114.0 | .30 | .15 |
| May | 85.6 | .22 | .00 |
| June | 108.0 | .28 | .00 |
| July | 79.4 | .21 | .07 |
| August | 61.0 | .16 | .00 |
| September | 71.9 | .19 | .04 |
| October | 49.2 | .13 | .00 |
| November | 17.9 | .05 | .83 |
| December | 49.2 | .13 | .30 |
| Total irrigation | 689.8 | 1.81 | 10.06 |
| Total, including rainfall | ..... | 2.64 | ..... |

CALIFORNIA-MEXICO LAND AND CATTLE COMPANY'S FLUME.

This station was established November 28, 1904. It is located 3½ miles east of Mexicala. The total area irrigated under this flume is 575 acres. The soil is classified as "Imperial sandy loam." In December, 1904, the entire area was sown to barley, 75 acres were cut for hay, averaging 1¼ tons to the acre, the balance of the acreage was used for pasturage. The crop was equally as good over the entire area as that on the 75 acres which was cut for hay. In May, 1905, the entire area was sown to Kaffir corn. This crop was poor and scattering and used in the fall for pasturage. This area received an ample supply of water for the crops raised.

The rainfall for this station is taken from the United States Weather Bureau records kept at Calexico, Cal.

*Monthly duty of water under California-Mexico Land and Cattle Company's flume during 1905.*

| Month. | Acre-feet. | | Rainfall in inches. |
|---|---|---|---|
| | Total. | Per acre. | |
| January | 67.6 | 0.12 | 1.50 |
| February | 5.6 | .01 | 3.76 |
| March | 30.7 | .05 | .91 |
| April | 113.0 | .20 | .50 |
| May | 313.0 | .55 | .00 |
| June | 214.0 | .37 | .00 |
| July | 332.0 | .58 | .03 |
| August | 289.0 | .50 | .00 |
| September | 131.0 | .23 | .13 |
| October | 91.7 | .16 | .00 |
| November | 66.0 | .11 | 1.96 |
| December | 104.0 | .18 | .54 |
| Total irrigation | 1,757.6 | 3.06 | 9.33 |
| Total, including rainfall | ..... | 3.84 | ..... |



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#### MISCELLANEOUS MEASUREMENTS IN COLORADO RIVER DRAINAGE BASIN.

The following miscellaneous measurements were made in canals in the Colorado River drainage basin by W. D. Smith during 1905:

*Miscellaneous discharge measurements made in Colorado River drainage basin in 1905.*

| Date. | Locality. | Width. | Area of section. | Mean velocity. | Discharge. |
|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Sec.-ft.* |
| February 15 ... | Imperial canal in Mexico immediately below Quail River waste gate.[a] | ..... | 560 | 3.46 | 1,937 |
| February 28 ... | ....do ..... | ..... | 556 | 3.28 | 1,821 |
| December 17... | Imperial canal in Mexico immediately below Quail River cut-off.[b] | 170 | 1,640 | 3.21 | 5,265 |
| December ..... | Quail River cut-off in Mexico at point of diversion from Imperial canal.[b] | 150 | 632 | 2.68 | 1,693 |

[a] Quail River waste gate is in Mexico, 12 miles below heading No. 1 of the Imperial canal. Gagings by means of boat and cable were made at this point February 15 and 28 to determine amount of water being carried to Imperial Valley by the canal.

[b] For location and significance of this gaging see general description of Imperial canal, page 21. A measurement was made by means of boat and cable.

## THE GREAT BASIN DRAINAGE.

### GENERAL FEATURES.

The Great Basin drainage in California is comprised within the subdrainages, Sierra Nevada and Minor Great Basin. Within the Sierra Nevada drainage is a limited area of arid country lying on the eastern slope of the Sierra Nevadas. This area includes the Susan and Owens River drainage basins. Within the Minor Great Basin drainage lies the Mohave River drainage basin. Having no outlet to the sea, the entire drainage of these basins is lost mainly through evaporation from the lakes and sinks in which the waters of these rivers collect.

### SUSAN RIVER DRAINAGE BASIN.

#### DESCRIPTION OF BASIN.

Susan River has its source in the Sierra Nevada in northeastern California, and flows eastward, discharging into Honey Lake—one of the landlocked lakes of the Great Basin—of which it is the principal feeder. A considerable area of land is irrigated from the waters of the river below the gaging station, and during the last ten or twelve years several projects have been started for irrigating other extensive areas by the storage of its waters both above and below the town of Susanville.

#### SUSAN RIVER NEAR SUSANVILLE, CAL.

This station was established June 3, 1900, by L. H. Taylor. It is located about three-fourths of a mile southwest of Susanville, at the electric light plant.

The channel is straight for 150 feet above and 250 feet below the station. The current is swift. There is a riffle immediately above the cable. The right bank is high and is composed of clay covered with vegetation. It is not liable to overflow. The left bank is low, liable to overflow, and covered with a sparse growth of willows. The bed of the stream is composed of gravel and cobblestones and is permanent. A short distance above the station a small irrigating ditch, known as the "Masten ditch," is taken out on the right bank.

High-water measurements are made by means of a cable and car. Measurements at low and ordinary stages are made by wading. The initial point for soundings is a post in the fence in line with the cable, 34.8 feet from the cable support on the left bank.

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On December 20, 1903, the station was reestablished, and the datum of the gage was raised 2.00 feet. A gage is also placed in the flume near the head of Masten ditch. During 1905 the gage was read once each day by James Branham. Bench marks were established as follows: (1) A nail in the fence post which is used as the initial point for soundings; elevation, 11.35 feet. (2) A nail in the cable post; elevation, 9.00 feet. (3) A nail in the cottonwood tree to which the cable is attached; elevation, 10.00 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 51, p 408; 66, pp 115–116; 85, p 123; 100, pp 204–205; 133, p 197.
Discharge: 51, p 408; 66, p 116; 100, p 205; 133, p 197.
Discharge, monthly: 75, p 190; 133, p 198.
Gage heights: 51, p 408; 66, p 116; 85, p 124; 100, p 205; 133, p 198.
Rating table: 566, p 175.

*Discharge measurements of Susan River near Susanville, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 21 | J. Branham | 44 | 92 | 4.79 | 6.60 | 441 |
| May 12 | do | 29 | 48 | 3.27 | 5.40 | 157 |
| June 12 | do | 25 | 31 | 2.32 | 4.70 | 72 |
| June 25 | do | 24 | 18 | 1.66 | 4.20 | 30 |
| July 23 | do | 18 | 10.8 | 1.19 | 3.85 | 12.8 |
| August 29 | do | 14 | 8.1 | 0.85 | 3.75 | 6.9 |
| September 26 | do | 19 | 13.6 | 1.13 | 4.00 | 15.4 |

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*Daily gage height, in feet, of Susan River near Susanville, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.95 | 5.2 | 5.25 | 6.15 | 5.95 | 5.15 | 4.1 | 4.1 | 3.8 | 3.8 | 4.0 | 4.0 |
| 2 | 4.8 | 5.2 | 5.25 | 5.95 | 5.9 | 5.1 | 4.1 | 4.1 | 3.8 | 3.8 | 4.0 | 4.0 |
| 3 | 4.75 | 5.2 | 5.25 | 5.95 | 5.8 | 5.05 | 4.45 | 4.1 | 3.8 | 3.9 | 4.0 | 4.0 |
| 4 | 4.7 | 5.2 | 5.25 | 5.9 | 5.8 | 5.05 | 4.8 | 4.1 | 3.8 | 3.95 | 4.0 | 4.0 |
| 5 | 4.65 | 5.15 | 5.25 | 5.9 | 5.65 | 5.0 | 4.6 | 4.1 | 3.85 | 3.95 | 4.0 | 4.0 |
| 6 | 4.6 | 5.05 | 5.25 | 6.0 | 5.55 | 5.0 | 4.4 | 4.1 | 3.85 | 3.95 | 4.0 | 4.0 |
| 7 | 4.6 | 4.85 | 5.25 | 6.1 | 5.5 | 5.0 | 4.25 | 4.1 | 3.85 | 4.0 | 4.0 | 4.0 |
| 8 | 4.55 | 4.85 | 5.25 | 6.1 | 5.5 | 4.9 | 4.1 | 4.0 | 3.85 | 3.95 | 4.0 | 4.0 |
| 9 | 4.55 | 4.75 | 5.2 | 6.1 | 5.5 | 4.85 | 4.1 | 3.9 | 3.85 | 3.9 | 4.0 | 4.0 |
| 10 | 4.55 | 4.8 | 5.2 | 6.2 | 5.45 | 4.75 | 4.0 | 3.8 | 3.85 | 3.9 | 4.0 | 4.0 |
| 11 | 4.55 | 4.7 | 5.2 | 6.1 | 5.4 | 4.7 | 4.0 | 3.8 | 3.9 | 3.9 | 4.0 | 4.0 |
| 12 | 4.6 | 4.65 | 5.4 | 6.1 | 5.4 | 4.7 | 4.0 | 3.8 | 3.9 | 3.9 | 4.0 | 4.0 |
| 13 | 4.65 | 4.55 | 5.9 | 6.1 | 5.35 | 4.65 | 3.95 | 3.8 | 3.9 | 3.9 | 4.0 | 4.0 |
| 14 | 4.7 | 4.5 | 5.9 | 6.1 | 5.3 | 4.65 | 4.2 | 3.8 | 3.85 | 3.9 | 4.0 | 4.0 |
| 15 | 4.7 | 4.45 | 6.05 | 6.1 | 5.3 | 4.6 | 4.2 | 3.75 | 3.85 | 3.9 | 4.0 | 4.0 |
| 16 | 4.7 | 4.45 | 6.1 | 6.1 | 5.4 | 4.5 | 4.2 | 3.75 | 3.8 | 3.9 | 4.0 | 4.0 |
| 17 | 4.7 | 4.5 | 6.05 | 6.05 | 5.4 | 4.5 | 4.0 | 3.75 | 3.8 | 4.0 | 4.0 | 4.0 |
| 18 | 4.65 | 4.55 | 6.0 | 6.05 | 5.4 | 4.4 | 4.0 | 3.75 | 3.8 | 4.05 | 4.0 | 4.0 |
| 19 | 4.65 | 5.05 | 6.6 | 6.05 | 5.4 | 4.4 | 4.1 | 3.75 | 3.9 | 4.0 | 4.0 | 4.0 |
| 20 | 4.65 | 5.35 | 6.25 | 5.95 | 5.4 | 4.4 | 4.05 | 3.75 | 3.9 | 4.0 | 4.0 | 4.0 |
| 21 | 4.65 | 5.35 | 6.45 | 5.8 | 5.4 | 4.3 | 3.9 | 3.8 | 3.95 | 4.0 | 4.0 | 4.0 |
| 22 | 4.8 | 5.25 | 6.15 | 5.8 | 5.4 | 4.3 | 3.9 | 3.8 | 3.95 | 4.0 | 4.0 | 4.0 |
| 23 | 5.5 | 5.1 | 6.1 | 5.8 | 5.35 | 4.25 | 3.85 | 3.8 | 3.95 | 4.0 | 4.05 | 4.0 |
| 24 | 5.4 | 5.1 | 6.05 | 5.85 | 5.35 | 4.2 | 3.85 | 3.75 | 3.95 | 4.0 | 4.05 | 4.0 |
| 25 | 5.2 | 5.2 | 5.85 | 5.9 | 5.3 | 4.2 | 3.85 | 3.75 | 3.95 | 4.0 | 4.1 | 4.0 |
| 26 | 4.95 | 5.2 | 6.9 | 6.0 | 5.3 | 4.2 | 3.85 | 3.75 | 4.0 | 4.0 | 4.1 | 4.0 |
| 27 | 4.9 | 5.25 | 6.3 | 6.0 | 5.3 | 4.2 | 3.8 | 3.75 | 3.9 | 4.0 | 4.1 | 4.0 |
| 28 | 4.9 | 5.25 | 6.1 | 6.0 | 5.25 | 4.2 | 3.8 | 3.75 | 4.0 | 4.0 | 4.05 | 4.0 |
| 29 | 4.85 | ..... | 6.0 | 6.0 | 5.25 | 4.15 | 3.75 | 3.8 | 3.95 | 4.0 | 4.05 | 4.0 |
| 30 | 4.8 | ..... | 6.1 | 6.0 | 5.2 | 4.15 | 3.75 | 3.8 | 3.9 | 4.0 | 4.0 | 4.0 |
| 31 | 4.8 | ..... | 6.0 | ..... | 5.2 | ..... | 4.1 | 3.8 | ..... | 4.0 | ..... | 4.0 |

*Station rating table for Susan River near Susanville, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.75 | 7 | 4.60 | 59 | 5.50 | 168 | 6.40 | 356 |
| 3.80 | 9 | 4.70 | 68 | 5.60 | 185 | 6.50 | 382 |
| 3.90 | 13 | 4.80 | 77 | 5.70 | 203 | 6.60 | 410 |
| 4.00 | 18 | 4.90 | 87 | 5.80 | 222 | 6.70 | 440 |
| 4.10 | 24 | 5.00 | 98 | 5.90 | 242 | 6.80 | 470 |
| 4.20 | 30 | 5.10 | 110 | 6.00 | 262 | 6.90 | 500 |
| 4.30 | 37 | 5.20 | 123 | 6.10 | 284 | | |
| 4.40 | 44 | 5.30 | 137 | 6.20 | 307 | | |
| 4.50 | 51 | 5.40 | 152 | 6.30 | 331 | | |

NOTE.—The above table is based on 11 discharge measurements made during 1904 and 1905 and is well defined.

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*Estimated monthly discharge of Susan River near Susanville, Cal., for 1905.*

[Drainage area, 256 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 168 | 55 | 76.9 | 4,728 | 0.300 | 0.346 |
| February | 144 | 48 | 96.9 | 5,382 | .379 | .395 |
| March | 500 | 123 | 234 | 14,390 | .914 | 1.05 |
| April | 307 | 222 | 264 | 15,710 | 1.03 | 1.15 |
| May | 252 | 123 | 160 | 9,838 | .625 | .721 |
| June | 116 | 27 | 61.3 | 3,648 | .239 | .267 |
| July | 77 | 7 | 23.4 | 1,439 | .091 | .105 |
| August | 24 | 7 | 12.1 | 744 | .047 | .054 |
| September | 18 | 9 | 12.3 | 732 | .048 | .054 |
| October | 21 | 9 | 15.7 | 965 | .061 | .070 |
| November | 24 | 18 | 19.0 | 1,131 | .074 | .083 |
| December | 18 | 18 | 18.0 | 1,107 | .070 | .081 |
| The year | 500 | 7 | 82.8 | 59,810 | .323 | 4.38 |

## WILLOW CREEK AT MERRILLVILLE, CAL.

This station was established June 18, 1904, by S. G. Bennett. It is located at the old bridge, 100 feet above the present wagon bridge at Merrillville.

The channel is straight above and below the bridge for 100 feet. The banks on each side are low, but not subject to overflow, and there is very little fluctuation in the discharge of the creek. The bed of the stream is composed of gravel and is not subject to much change.

Discharge measurements are made from the bridge. The initial point for soundings is on the left bank of the stream.

The gage is a staff fastened vertically to the left end of the bridge. During 1905 the gage was read once each day by R. W. Hurlbut.

A description of this station and gage height and discharge data are contained in Water-Supply Paper No. 134, United States Geological Survey, pages 199–200.

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*Daily gage height, in feet, of Willow Creek at Merrillville, Cal., in 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.1 | 1.1 | 0.95 | 1.1 | 0.9 | 0.95 | 0.9 | 0.95 | 1.0 | 1.1 | 1.3 | 1.25 |
| 2 | 1.05 | 1.1 | 1.0 | 1.05 | .9 | .95 | .9 | .95 | 1.0 | 1.1 | 1.25 | 1.3 |
| 3 | 1.0 | 1.1 | 1.0 | 1.0 | .95 | .95 | .9 | .95 | 1.0 | 1.1 | 1.2 | 1.3 |
| 4 | 1.0 | 1.05 | 1.0 | 1.0 | .95 | .95 | .9 | .95 | 1.0 | 1.1 | 1.2 | 1.3 |
| 5 | 1.0 | 1.1 | .95 | 1.0 | .95 | .95 | .9 | .95 | 1.0 | 1.1 | 1.2 | 1.3 |
| 6 | 1.0 | 1.05 | .95 | 1.0 | .95 | .95 | .9 | .95 | 1.0 | 1.2 | 1.2 | 1.3 |
| 7 | 1.0 | 1.0 | 1.0 | 1.0 | .95 | .95 | .9 | .95 | 1.0 | 1.3 | 1.2 | 1.3 |
| 8 | 1.0 | 1.0 | 1.05 | 1.0 | .95 | 1.0 | .9 | .95 | 1.0 | 1.2 | 1.2 | 1.3 |
| 9 | 1.0 | 1.0 | 1.0 | 1.0 | .95 | 1.0 | .9 | 1.0 | 1.0 | 1.2 | 1.2 | 1.3 |
| 10 | 1.0 | 1.0 | 1.0 | .95 | 1.0 | .95 | .95 | 1.0 | 1.0 | 1.2 | 1.2 | 1.3 |
| 11 | 1.0 | 1.0 | 1.0 | .95 | 1.05 | .95 | .95 | 1.0 | 1.0 | 1.2 | 1.2 | 1.3 |
| 12 | 1.0 | 1.0 | 1.0 | .95 | 1.1 | .95 | 1.05 | 1.0 | 1.0 | 1.2 | 1.2 | 1.3 |
| 13 | 1.0 | 1.0 | 1.05 | 1.0 | 1.05 | .95 | 1.05 | 1.0 | 1.0 | 1.2 | 1.2 | 1.3 |
| 14 | 1.05 | 1.0 | .95 | 1.0 | 1.0 | .95 | 1.0 | 1.0 | 1.0 | 1.2 | 1.2 | 1.3 |
| 15 | 1.05 | .95 | 1.05 | 1.0 | .95 | .95 | 1.0 | 1.0 | 1.0 | 1.2 | 1.2 | 1.3 |
| 16 | 1.05 | 1.0 | 1.1 | 1.0 | .9 | .95 | 1.0 | 1.0 | 1.0 | 1.2 | 1.2 | 1.3 |
| 17 | 1.05 | 1.0 | 1.1 | 1.0 | .9 | .95 | .95 | 1.0 | 1.05 | 1.2 | 1.2 | 1.3 |
| 18 | 1.05 | 1.0 | 1.05 | 1.0 | .9 | .95 | .95 | 1.0 | 1.05 | 1.2 | 1.2 | 1.3 |
| 19 | 1.05 | 1.25 | 1.1 | 1.0 | .9 | .95 | .95 | 1.0 | 1.05 | 1.2 | 1.2 | 1.3 |
| 20 | 1.0 | 1.15 | 1.05 | 1.0 | .9 | .95 | .95 | 1.0 | 1.05 | 1.2 | 1.2 | 1.3 |
| 21 | 1.05 | 1.05 | 1.05 | 1.0 | .9 | .95 | .95 | 1.0 | 1.05 | 1.2 | 1.2 | 1.3 |
| 22 | 1.1 | 1.05 | 1.05 | 1.0 | .95 | .95 | .95 | 1.0 | 1.05 | 1.25 | 1.2 | 1.3 |
| 23 | 1.1 | 1.05 | 1.05 | .9 | .95 | .95 | .95 | 1.0 | 1.05 | 1.25 | 1 2 | 1.3 |
| 24 | 1.1 | 1.0 | 1.0 | .9 | .95 | .95 | .95 | 1.0 | 1.05 | 1.25 | 1.2 | 1.3 |
| 25 | 1.05 | 1.0 | 1.0 | .95 | .95 | .95 | .95 | 1.0 | 1.05 | 1.25 | 1.2 | 1.3 |
| 26 | 1.0 | 1.05 | 1.1 | .95 | 1.0 | .95 | .95 | 1.0 | 1.05 | 1.2 | 1.2 | 1.3 |
| 27 | 1.0 | 1.0 | 1.1 | .95 | 1.0 | .95 | .95 | 1.0 | 1.1 | 1.2 | 1.2 | 1.3 |
| 28 | 1.0 | 1.0 | 1.0 | .95 | 1.0 | .95 | .95 | 1.0 | 1.15 | 1.2 | 1.25 | 1.3 |
| 29 | 1.0 | ..... | 1.1 | .9 | .95 | .95 | .95 | 1.0 | 1.2 | 1.2 | 1.25 | 1.3 |
| 30 | 1.0 | ..... | 1.05 | .9 | .95 | .9 | .95 | 1.0 | 1.1 | 1.2 | 1.25 | 1.3 |
| 31 | 1.0 | ..... | 1.05 | ..... | .95 | ..... | .95 | 1.0 | ..... | 1.25 | ..... | 1.3 |

*Station rating table for Willow Creek at Merrillville, Cal., from July 1, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.90 | 16 | 1.10 | 20 | 1.20 | 22 | 1.30 | 24 |
| 1.00 | 18 | | | | | | |

NOTE.—The above table is based on four discharge measurements made during 1904, and is fairly well defined.

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*Estimated monthly discharge of Willow Creek at Merrillville, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 20 | 18 | 18.5 | 1,138 |
| February | 23 | 17 | 18.8 | 1,044 |
| March | 20 | 17 | 18.6 | 1,144 |
| April | 20 | 16 | 17.6 | 1,047 |
| May | 20 | 16 | 17.1 | 1,051 |
| June | 18 | 16 | 17.0 | 1,012 |
| July | 19 | 16 | 16.9 | 1,039 |
| August | 18 | 17 | 17.7 | 1,088 |
| September | 22 | 18 | 18.7 | 1,113 |
| October | 24 | 20 | 21.9 | 1,347 |
| November | 24 | 22 | 22.2 | 1,321 |
| December | 24 | 23 | 24.0 | 1,476 |
| The year | 24 | 16 | 19.1 | 13,820 |

### WILLOW CREEK NEAR STANDISH, CAL.

This station was originally established June 4, 1900. It was reestablished January 1, 1905, and discontinued December 31 of the same year. It is located at the bridge on the road from Susanville to Hot Springs and is about 1½ miles above the junction of the creek with Susan River. It is about 4 miles west of north from Standish.

The channel is straight for 300 feet above and 250 feet below the station. The right bank is rather low and is subject to overflow at extreme high water; the left bank is high and not liable to overflow. The stream bed is sandy and liable to shift somewhat.

Discharge measurements are made from the bridge. The initial point for soundings is on the end of the bridge on the left bank.

The gage is a staff fastened vertically to the left abutment of the bridge. During 1905 the gage was read once each day by T. E. Ravenscroft

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 51, p 407; 66, p 115.
Discharge: 51, p 407.
Gage heights: 51, p 407; 66, p 115.

*Discharge measurements of Willow Creek near Standish, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 24 | J. Branham | 57 | 117 | 0.80 | 6.15 | 94 |
| January 29 | do | 57 | 87 | .79 | 5.35 | 69 |
| February 26 | do | 57 | 105 | .79 | 5.75 | 83 |
| April 23 | do | 32 | 21 | .95 | 4.00 | 20 |
| November 19 | do | 57 | 56 | .61 | 4.80 | 34 |

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*Daily gage height, in feet, of Willow Creek near Standish, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.6 | 6.8 | 5.0 | 5.5 | 4.0 | 4.0 | 3.0 | 4.0 | 4.2 | 5.0 | 5.0 | 5.0 |
| 2 | 6.6 | 6.7 | 4.8 | 5.3 | 4.0 | 4.0 | 3.0 | 4.0 | 4.5 | 4.8 | 5.1 | 5.3 |
| 3 | 5.0 | 5.9 | 4.0 | 5.0 | 4.0 | 4.0 | 3.0 | 4.0 | 4.4 | 4.6 | 5.0 | 5.2 |
| 4 | 5.0 | ..... | 4.0 | 5.0 | 4.0 | 4.0 | 6.0 | 4.0 | 4.4 | 4.3 | 5.0 | 5.0 |
| 5 | 4.6 | 5.8 | 4.0 | 4.8 | 4.0 | 4.0 | 5.8 | 4.0 | 4.4 | 4.0 | 5.0 | 5.1 |
| 6 | 4.6 | 6.0 | 4.4 | 4.5 | 4.0 | 4.0 | 4.8 | 4.0 | 4.4 | 4.0 | 5.1 | 5.0 |
| 7 | 4.6 | 6.0 | 4.4 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.4 | 4.0 | 5.2 | 5.2 |
| 8 | 4.6 | 5.8 | 4.4 | 4.0 | 4.0 | 4.2 | 4.0 | 4.0 | 4.4 | 4.2 | 5.0 | 4.1 |
| 9 | 4.6 | 5.6 | 4.0 | 4.0 | 4.0 | 4.1 | 4.0 | 4.0 | 4.4 | 4.2 | 5.0 | 4.1 |
| 10 | 4.6 | 5.0 | 4 0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.1 | 5.2 | 4.4 |
| 11 | 4.6 | 5.0 | 4.4 | 4.0 | 4.2 | 4.0 | 4.0 | 4.2 | 4.0 | 4.1 | 5.1 | 4.4 |
| 12 | 4.7 | 5.0 | 4.0 | 3.8 | 4.2 | 4.0 | 6.0 | 4.0 | 4.0 | 4.0 | 4.6 | 4.4 |
| 13 | 4.7 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 6.0 | 4.0 | 4.0 | 4.0 | 4.4 | 4.3 |
| 14 | 4.7 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.8 | 4.0 | 6.0 | 4.0 | 4.4 | 4.5 |
| 15 | 5.8 | 4.6 | 4.4 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.8 | 4.0 | 4.4 | 4.1 |
| 16 | 5.8 | 4.7 | 4.4 | 4.0 | 4.0 | 4.0 | 5.8 | 4.0 | 5.0 | 4.1 | 4.6 | 4.1 |
| 17 | 6.0 | 4.7 | 4.4 | 4.0 | 4.0 | 4.0 | 5.8 | 4.0 | 5.0 | 4.5 | 4.8 | 4.3 |
| 18 | 6.0 | 4.7 | 4.4 | 4.0 | 4.0 | 4.0 | 5.8 | 4.2 | 5.0 | 4.5 | 4.8 | 4.3 |
| 19 | 6.4 | 5.1 | 5.0 | 4.0 | 4.0 | 4.0 | 6.0 | 4.2 | 5.0 | 4.5 | 5.0 | 4.3 |
| 20 | 6.35 | 6.0 | 5.0 | 4.0 | 4.0 | 4.0 | 6.0 | 4.6 | 5.0 | 4.5 | 5.0 | 4.3 |
| 21 | 6.0 | 7.8 | 5.2 | 4.0 | 4.1 | 4.0 | 6.0 | 4.5 | 4.8 | 4.5 | 4.8 | 4.0 |
| 22 | 7.6 | 7.8 | 5.2 | 4.0 | 4.1 | 4.0 | 5.0 | 4.6 | 4.8 | 4.5 | 4.6 | 5.0 |
| 23 | 7.8 | 7.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.2 | 4.8 | 5.0 | 4.6 | 5.0 |
| 24 | 6.0 | 6.2 | 4.8 | 4.0 | 4.0 | 4.0 | 4.8 | 4.0 | 4.6 | 5.1 | 4.5 | 5.2 |
| 25 | 6.0 | 6.0 | 4.6 | 4.0 | 4.0 | 4.0 | 4.1 | 4.0 | 4.5 | 5.2 | 4.4 | 5.0 |
| 26 | 5.8 | 6.3 | 5.3 | 4.0 | 4.0 | 6.2 | 4.0 | 4.2 | 5.0 | 5.2 | 4.8 | 5.2 |
| 27 | 5.6 | 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.2 | 6.0 | 5.1 | 4.8 | 5.3 |
| 28 | 5.6 | 5.0 | 5.0 | 4.0 | 3.8 | 4.0 | 4.0 | 4.2 | 5.8 | 5.5 | 5.0 | 5.3 |
| 29 | 5.7 | ..... | 5.0 | 4.0 | 3.8 | 4.0 | 4.0 | 4.2 | 5.8 | 5.2 | 5.0 | 5.3 |
| 30 | 5.0 | ..... | 5.0 | 4.0 | 3.8 | 3.6 | 4.0 | 4.3 | 5.0 | 5.0 | 5.0 | 5.3 |
| 31 | 5.6 | ..... | 5.5 | ..... | ..... | ..... | 4.0 | 4.2 | ..... | 5.0 | ..... | 5.3 |

*Station rating table for Willow Creek near Standish, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.60 | 10 | 4.60 | 31 | 5.60 | 74 | 6.60 | 141 |
| 3.70 | 11 | 4.70 | 34 | 5.70 | 80 | 6.70 | 149 |
| 3.80 | 13 | 4.80 | 37 | 5.80 | 86 | 6.80 | 157 |
| 3.90 | 15 | 4.90 | 41 | 5.90 | 92 | 6.90 | 165 |
| 4.00 | 17 | 5.00 | 45 | 6.00 | 98 | 7.00 | 173 |
| 4.10 | 19 | 5.10 | 49 | 6.10 | 105 | 7.20 | 189 |
| 4.20 | 21 | 5.20 | 54 | 6.20 | 112 | 7.40 | 205 |
| 4.30 | 23 | 5.30 | 59 | 6.30 | 119 | 7.60 | 221 |
| 4.40 | 25 | 5.40 | 64 | 6.40 | 126 | 7.80 | 238 |
| 4.50 | 28 | 5.50 | 69 | 6.50 | 133 | | |

NOTE.—The above table is based on five discharge measurements made during 1905 and is not well defined.

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*Estimated monthly discharge of Willow Creek near Standish, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 238 | 31 | 80.4 | 4,944 |
| February[a] | 238 | 31 | 89.4 | 4,965 |
| March | 69 | 17 | 33.5 | 2,060 |
| April | 69 | 17 | 22.9 | 1,363 |
| May[a] | 21 | 13 | 17.0 | 1,045 |
| June | 112 | 10 | 21.1 | 1,256 |
| July | 98 | 0 | 46.2 | 2,841 |
| August | 31 | 17 | 19.6 | 1,205 |
| September | 98 | 17 | 41.0 | 2,440 |
| October | 69 | 17 | 31.8 | 1,955 |
| November | 54 | 25 | 39.6 | 2,356 |
| December | 59 | 17 | 38.7 | 2,380 |
| The year | 238 | 0 | 40.1 | 28,810 |

[a] Discharge interpolated February 4 and May 31.

## OWENS RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Owens River has its source in the Sierra Nevadas in eastern California and flows southeast parallel with this range, finally discharging its waters into Owens Lake. This basin has a length from north to south of approximately 150 miles with a width of from 20 to 25 miles. It lies between the Sierra Nevadas on the west and the White Mountains on the east. Practically the entire flow of this river is derived from the Sierra Nevadas, as it drains the entire eastern slope of this range from Mount Lyell on the north to a point some distance below Mount Whitney on the south. The White Mountains furnish no water for this stream except in times of exceptionally heavy rain storms, which seldom occur on this range. There are numerous tributaries entering Owens River from the west which have their source in the high elevations of the Sierra Nevadas, extending from the northern to the southern limits of this basin. The topography of the portion of the Sierra Nevadas which is drained by this stream is extremely rough and precipitous, the mountains rising abruptly from Owens Valley to elevations of 13,000 to 14,000 feet. The formation is of granite, with very little soil covering and sparse timber growth. Numerous lakes and marshes are found in the upper reaches of this portion of the drainage basin. Owens River, a short distance below its source, enters a flat, swampy country known as Long Valley, where a considerable quantity of its flow is used for the irrigation of meadow lands for stock raising. This water returns to the river channel at the lower end of this valley, at which point the stream enters a deep, narrow gorge with heavy grade. As the river breaks from this canyon it enters Owens Valley, through which it flows for a distance of about 80 miles, finally discharging into Owens Lake. The gaging station at Round Valley is located at the lower end of this canyon. Below this point numerous diversions are made for the irrigation of land in Owens Valley, where the soil is extensively cultivated and large areas are used for the raising of hay and grain. This country is particularly adapted to stock raising, which is carried on extensively throughout the valley. There are numerous opportunities for the construction of storage reservoirs within this basin, both on the main stream and also on the upper reaches of its tributaries, although none have been constructed as yet. The precipitation is extremely light within the area of this basin with the exception of the high elevations of the Sierra Nevadas, where there is a heavy fall of snow. The

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melting of the snow in the spring and summer months feeds the numerous tributaries of this river, insuring a continued flow throughout the year.

The gaging stations on canals taking water from Owens River may be considered as temporary. The gage rods in most instances are securely fastened to footbridges and are not liable to change. No permanent bench marks were established.

### OWENS RIVER NEAR ROUND VALLEY, CAL.

This station was established August 3, 1903, by J. C. Clausen. It is located at the footbridge, 700 feet above the junction of Owens River and Rock Creek.

The river at this point cuts through a lava deposit about 100 feet thick and forms a gorge, which is about 250 feet wide at the top. The channel is straight for 175 feet above and 250 feet below the station. The current is swift at all stages. Both banks are high and rocky and are not liable to overflow. The bed of the stream is composed of rock and lava bowlders and is not subject to much change.

Discharge measurements are made from the single-span footbridge to which the gage is attached. The bridge is 37 feet long and has a clear span of 35 feet. The initial point for soundings is the anchor bolt of the right abutment.

The gage is a vertical rod, fastened to the concrete bridge abutment on the left bank. During 1905 the gage was read once each day by T. E. Jones. The bench mark is a bolt set in a lava bowlder 97.4 feet north of the right abutment.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 206; 134, p 200.
Discharge: 100, p 206; 134, p 201.
Discharge, monthly: 134, p 203.
Gage heights, 100, p 207; 134, p 202.
Rating table: 134, p 203.

*Discharge measurements of Owens River near Round Valley, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 16 | R. J. Taylor | 34 | 73 | 2.52 | 1.97 | 184 |
| February 9 | do | 34 | 76 | 2.70 | 1.95 | 175 |
| April 4 | J. S. Evans | 34 | 72 | 2.49 | 2.00 | 179 |
| May 22 | do | 34 | 91 | 3.36 | 2.39 | 306 |
| June 27 | do | 34 | 102 | 3.74 | 2.58 | 382 |
| July 25 | do | 34 | 76 | 2.73 | 2.15 | 207 |
| August 15 | do | 34 | 72 | 2.12 | 1.90 | 154 |
| September 8 | do | 34 | 76 | 2.33 | 2.00 | 177 |
| September 27 | do | 24 | 72 | 2.15 | 1.90 | 155 |
| November 2 | F. R. S. Buttemer | 34 | 72 | 2.28 | 1.80 | 164 |
| November 24 | do | 34 | 75 | 2.40 | 1.85 | 180 |
| December 10 | do | 34 | 70 | 2.16 | 1.73 | 151 |

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*Daily gage height, in feet, of Owens River near Round Valley, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.15 | 2.2 | 2.2 | 1.9 | 2.1 | 2.3 | 2.5 | 2.1 | 1.9 | 2.0 | 1.8 | 1.9 |
| 2 | 2.1 | 2.15 | 2.25 | 1.95 | 2.1 | 2.3 | 2.5 | 2.05 | 1.9 | 2.0 | 1.8 | 1.9 |
| 3 | 2.1 | 2.1 | 2.2 | 2.0 | 2.1 | 2.3 | 2.6 | 2.05 | 1.9 | 2.0 | 1.75 | 1.95 |
| 4 | 2.0 | 2.1 | 2.2 | 2.0 | 2.1 | 2.3 | 2.6 | 2.0 | 1.9 | 1.95 | 1.75 | 1.95 |
| 5 | 2.0 | 2.1 | 2.2 | 2.0 | 2.1 | 2.3 | 2.6 | 2.0 | 1.95 | 1.95 | 1.8 | 1.95 |
| 6 | 2.0 | 2.0 | 2.25 | 2.0 | 2.05 | 2.3 | 2.6 | 1.95 | 2.0 | 1.9 | 1.8 | 2.0 |
| 7 | 2.0 | 2.1 | 2.25 | 2.0 | 2.0 | 2.35 | 2.5 | 1.95 | 2.0 | 1.9 | 1.85 | 2.0 |
| 8 | 2.0 | 2.1 | 2.2 | 2.0 | 2.0 | 2.35 | 2.5 | 2.0 | 2.0 | 1.9 | 1.85 | 2.0 |
| 9 | 2.0 | 2.1 | 2.1 | 2.1 | 2.0 | 2.4 | 2.5 | 2.0 | 2.0 | 1.9 | 1.9 | 1.95 |
| 10 | 2.0 | 2.1 | 2.1 | 2.1 | 2.0 | 2.4 | 2.5 | 2.0 | 2.0 | 1.95 | 1.9 | 1.9 |
| 11 | 2.0 | 2.1 | 2.0 | 2.0 | 2.0 | 2.4 | 2.5 | 1.9 | 2.0 | 1.95 | 1.9 | 1.9 |
| 12 | 1.95 | 2.0 | 2.0 | 2.0 | 2.0 | 2.55 | 2.45 | 1.9 | 2.0 | 2.0 | 1.9 | 1.9 |
| 13 | 1.95 | 2.0 | 2.5 | 2.0 | 2.0 | 2.7 | 2.4 | 1.9 | 2.0 | 2.0 | 1.9 | 1.9 |
| 14 | 1.9 | 2.0 | 2.15 | 1.95 | 2.0 | 2.75 | 2.4 | 2.0 | 2.0 | 2.0 | 1.95 | 1.85 |
| 15 | 1.9 | 2.0 | 2.15 | 1.9 | 2.0 | 2.75 | 2.4 | 2.0 | 2.0 | 2.0 | 2.0 | 1.85 |
| 16 | 1.9 | 2.0 | 2.15 | 1.9 | 2.0 | 2.75 | 2.3 | 2.0 | 2.0 | 2.0 | 2.0 | 1.85 |
| 17 | 1.95 | 2.0 | 2.1 | 1.95 | 2.2 | 3.0 | 2.2 | 1.9 | 2.0 | 1.95 | 2.0 | 1.8 |
| 18 | 1.95 | 2.1 | 2.1 | 1.95 | 2.35 | 3.0 | 2.2 | 1.9 | 2.0 | 1.95 | 2.0 | 1.8 |
| 19 | 2.0 | 2.2 | 2.05 | 1.95 | 2.35 | 3.0 | 2.2 | 1.9 | 2.0 | 1.9 | 2.0 | 1.8 |
| 20 | 2.0 | 2.1 | 2.05 | 1.95 | 2.4 | 3.0 | 2.2 | 1.85 | 2.0 | 1.85 | 2.0 | 1.75 |
| 21 | 2.1 | 2.0 | 2.1 | 1.9 | 2.4 | 3.0 | 2.15 | 1.85 | 2.0 | 1.85 | 2.0 | 1.75 |
| 22 | 2.1 | 1.95 | 2.1 | 1.9 | 2.4 | 3.0 | 2.1 | 1.9 | 2.0 | 1.85 | 2.0 | 1.75 |
| 23 | 2.0 | 1.95 | 2.1 | 1.9 | 2.4 | 3.0 | 2.1 | 1.9 | 2.0 | 1.85 | 2.0 | 1.75 |
| 24 | 2.0 | 1.9 | 2.0 | 1.95 | 2.4 | 2.95 | 2.1 | 1.9 | 2.0 | 1.85 | 2.0 | 1.75 |
| 25 | 2.1 | 1.85 | 2.0 | 1.95 | 2.4 | 2.8 | 2.1 | 1.9 | 2.0 | 1.8 | 2.0 | 1.75 |
| 26 | 2.1 | 1.85 | 2.0 | 1.95 | 2.4 | 2.7 | 2.0 | 1.9 | 2.0 | 1.8 | 2.0 | 1.8 |
| 27 | 2.1 | 2.0 | 2.0 | 1.95 | 2.45 | 2.6 | 2.0 | 1.9 | 2.0 | 1.75 | 2.0 | 1.8 |
| 28 | 2.1 | 2.1 | 1.95 | 2.0 | 2.55 | 2.6 | 2.0 | 1.9 | 2.0 | 1.75 | 1.95 | 1.8 |
| 29 | 2.1 | ..... | 1.9 | 2.05 | 2.5 | 2.55 | 2.0 | 1.9 | 2.0 | 1.75 | 1.9 | 1.8 |
| 30 | 2.2 | ..... | 1.9 | 2.05 | 2.4 | 2.5 | 2.0 | 1.9 | 2.0 | 1.75 | 1.9 | 1.8 |
| 31 | 2.2 | ..... | 1.9 | ..... | 2.3 | ..... | 2.0 | 1.9 | ..... | 1.75 | ..... | 1.8 |

*Station rating table for Owens River near Round Valley, Cal., from January 1 to October 10, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.80 | 134 | 2.20 | 240 | 2.60 | 377 | 3.00 | 533 |
| 1.90 | 158 | 2.30 | 271 | 2.70 | 415 | | |
| 2.00 | 184 | 2.40 | 304 | 2.80 | 453 | | |
| 2.10 | 211 | 2.50 | 339 | 2.90 | 493 | | |

NOTE.—The above table is based on 12 discharge measurements made during 1904–5. It is fairly well defined between gage heights 1.9 feet and 3.1 feet.

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*Station rating table for Owens River near Round Valley, Cal., from October 11 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.70 | 141 | 1.80 | 165 | 1.90 | 191 | 2.00 | 219 |

NOTE.—The above table is based on three discharge measurements made during the latter part of 1905 and is fairly well defined.

*Estimated monthly discharge of Owens River near Round Valley, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 240 | 158 | 193 | 11,870 |
| February | 240 | 146 | 196 | 10,890 |
| March | 339 | 158 | 213 | 13,100 |
| April | 211 | 158 | 177 | 10,530 |
| May | 358 | 184 | 246 | 15,130 |
| June | 533 | 271 | 392 | 23,330 |
| July | 377 | 184 | 275 | 16,910 |
| August | 211 | 146 | 169 | 10,390 |
| September | 184 | 158 | 180 | 10,710 |
| October | 219 | 153 | 180 | 11,070 |
| November | 219 | 153 | 197 | 11,720 |
| December | 219 | 153 | 179 | 11,010 |
| The year | 533 | 146 | 216 | 156,600 |

## ROCK CREEK NEAR ROUND VALLEY, CAL.

This station was established August 3, 1903, by J. C. Clausen. It is located at the wagon bridge on the road from Long Valley to Bishop 3,500 feet above the mouth of the creek.

The channel is straight for 50 feet above and 40 feet below the footbridge. The current is swift. Both banks are high and rocky and are not liable to overflow. The bed of the stream is composed of gravel and is not subject to much change.

Discharge measurements are made from a footbridge, which has a span of 18 feet. The initial point for soundings is on right bank of stream.

The gage is a vertical rod fastened to the left end of the bridge. During 1905 the gage was read once each day by T. E. Jones. The bench mark is a point marked on a lava rock 15 feet east of the left end of the footbridge.

Information in regard to this station is contained in the following water-supply papers of the United States Geological Survey:

Description: 100, p 207; 134, p 204.
Discharge: 100, p 207; 134, p 204.
Discharge, monthly: 134, p 207.
Gage heights: 100, p 208; 134, pp 205–206.
Rating table: 134, p 206.

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*Discharge measurements of Rock Creek near Round Valley, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 16 | R. J. Taylor | 13 | 16 | 1.76 | 1.52 | 28 |
| February 9 | do | 13 | 12.8 | 1.56 | 1.30 | 20 |
| April 4 | J. S. Evans | 13 | 12.8 | 1.55 | 1.40 | 19.9 |
| April 25 | do | 12 | 11.6 | 1.60 | 1.15 | 18.6 |
| May 24 | do | 14 | 19.3 | 2.02 | 1.80 | 39 |
| June 27 | do | 14.5 | 23 | 2.22 | 2.00 | 51 |
| July 25 | do | 13 | 12.6 | 1.90 | 1.30 | 24 |
| August 15 | do | 12.5 | 11.6 | 1.69 | 1.20 | 19.6 |
| September 8 | do | 12 | 11.2 | 1.57 | 1.18 | 18.6 |
| September 27 | do | 12 | 11.6 | 1.57 | 1.20 | 18.2 |
| November 2 | F. R. S. Buttemer | 13.5 | 14 | 1.50 | 1.35 | 21 |
| November 24 | do | 13.5 | 15.3 | 1.50 | 1.46 | 23 |
| December 10 | do | 13.5 | 16 | 1.69 | 1.60 | 27 |

*Daily gage height, in feet, of Rock Creek near Round Valley, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.7 | 2.1 | 1.4 | 1.4 | 1.3 | 1.7 | 1.8 | 1.35 | 1.2 | 1.2 | 1.3 | 1.6 |
| 2 | 1.6 | 1.6 | 1.4 | 1.4 | 1.4 | 1.65 | 1.8 | 1.35 | 1.2 | 1.2 | 1.3 | 1.6 |
| 3 | 1.6 | 1.6 | 1.4 | 1.4 | 1.35 | 1.65 | 1.75 | 1.35 | 1.2 | 1.2 | 1.3 | 1.65 |
| 4 | 1.5 | 1.5 | 1.4 | 1.4 | 1.3 | 1.6 | 1.75 | 1.3 | 1.2 | 1.25 | 1.3 | 1.65 |
| 5 | 1.5 | 1.5 | 1.35 | 1.4 | 1.3 | 1.6 | 1.8 | 1.3 | 1.2 | 1.25 | 1.3 | 1.65 |
| 6 | 1.5 | 1.5 | 1.3 | 1.4 | 1.2 | 1.6 | 1.8 | 1.25 | 1.2 | 1.25 | 1.3 | 1.65 |
| 7 | 1.5 | 1.4 | 1.2 | 1.4 | 1.2 | 1.5 | 1.9 | 1.3 | 1.2 | 1.25 | 1.3 | 1.65 |
| 8 | 1.5 | 1.35 | 1.2 | 1.4 | 1.2 | 1.6 | 2.0 | 1.3 | 1.2 | 1.25 | 1.25 | 1.65 |
| 9 | 1.4 | 1.3 | 1.1 | 1.3 | 1.25 | 1.7 | 2.0 | 1.4 | 1.2 | 1.25 | 1.25 | 1.65 |
| 10 | 1.3 | 1.3 | 1.1 | 1.3 | 1.25 | 1.7 | 2.0 | 1.4 | 1.2 | 1.25 | 1.25 | 1.6 |
| 11 | 1.3 | 1.3 | 1.2 | 1.35 | 1.25 | 1.8 | 2.0 | 1.3 | 1.2 | 1.2 | 1.2 | 1.6 |
| 12 | 1.3 | 1.4 | 1.2 | 1.25 | 1.3 | 2.1 | 2.0 | 1.25 | 1.2 | 1.2 | 1.2 | 1.6 |
| 13 | 1.3 | 1.4 | 1.5 | 1.25 | 1.3 | 2.1 | 2.0 | 1.25 | 1.2 | 1.2 | 1.25 | 1.6 |
| 14 | 1.3 | 1.4 | 1.35 | 1.2 | 1.3 | 2.15 | 2.0 | 1.2 | 1.15 | 1.2 | 1.3 | 1.6 |
| 15 | 1.3 | 1.4 | 1.35 | 1.2 | 1.3 | 2.3 | 2.0 | 1.2 | 1.1 | 1.25 | 1.3 | 1.6 |
| 16 | 1.35 | 1.45 | 1.4 | 1.2 | 1.3 | 2.3 | 1.9 | 1.15 | 1.1 | 1.25 | 1.3 | 1.6 |
| 17 | 1.4 | 1.5 | 1.45 | 1.15 | 1.7 | 2.35 | 1.8 | 1.15 | 1.15 | 1.3 | 1.3 | 1.6 |
| 18 | 1.4 | 1.4 | 1.45 | 1.1 | 1.9 | 2.4 | 1.7 | 1.15 | 1.15 | 1.3 | 1.3 | 1.6 |
| 19 | 1.45 | 1.4 | 1.4 | 1.1 | 1.9 | 2.5 | 1.6 | 1.15 | 1.2 | 1.3 | 1.3 | 1.6 |
| 20 | 1.45 | 1.4 | 1.4 | 1.0 | 1.9 | 2.45 | 1.6 | 1.15 | 1.2 | 1.3 | 1.3 | 1.6 |
| 21 | 1.7 | 1.4 | 1.35 | 1.0 | 1.8 | 2.4 | 1.6 | 1.15 | 1.25 | 1.3 | 1.3 | 1.55 |
| 22 | 1.7 | 1.4 | 1.35 | 1.0 | 1.8 | 2.3 | 1.55 | 1.15 | 1.3 | 1.3 | 1.35 | 1.55 |
| 23 | 1.6 | 1.4 | 1.3 | 1.0 | 1.85 | 2.3 | 1.55 | 1.15 | 1.3 | 1.3 | 1.4 | 1.55 |
| 24 | 1.6 | 1.45 | 1.35 | 1.1 | 1.75 | 2.2 | 1.5 | 1.1 | 1.3 | 1.3 | 1.45 | 1.5 |
| 25 | 1.5 | 1.45 | 1.4 | 1.15 | 1.7 | 2.2 | 1.5 | 1.1 | 1.3 | 1.3 | 1.5 | 1.5 |
| 26 | 1.4 | 1.45 | 1.4 | 1.15 | 1.7 | 2.1 | 1.4 | 1.1 | 1.25 | 1.3 | 1.5 | 1.55 |
| 27 | 1.4 | 1.4 | 1.4 | 1.15 | 1.75 | 2.0 | 1.4 | 1.1 | 1.2 | 1.25 | 1.55 | 1.6 |
| 28 | 1.4 | 1.4 | 1.4 | 1.2 | 1.9 | 1.9 | 1.3 | 1.1 | 1.2 | 1.25 | 1.6 | 1.6 |
| 29 | 1.4 | ..... | 1.4 | 1.2 | 1.8 | 1.85 | 1.25 | 1.1 | 1.2 | 1.25 | 1.6 | 1.6 |
| 30 | 1.3 | ..... | 1.4 | 1.25 | 1.8 | 1.8 | 1.25 | 1.15 | 1.2 | 1.25 | 1.55 | 1.6 |
| 31 | 1.3 | ..... | 1.4 | ..... | 1.75 | ..... | 1.4 | 1.15 | ..... | 1.25 | ..... | 1.55 |

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*Daily discharge, in second-feet, of Rock Creek near Round Valley, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 34 | 56 | 23 | 23 | 20 | 34 | 42 | 24 | 19 | 19 | 20 | 27 |
| 2 | 30 | 30 | 23 | 23 | 23 | 32 | 42 | 24 | 19 | 19 | 20 | 27 |
| 3 | 30 | 30 | 23 | 23 | 21 | 32 | 40 | 24 | 19 | 19 | 20 | 28 |
| 4 | 26 | 26 | 23 | 23 | 20 | 30 | 40 | 23 | 19 | 19 | 20 | 28 |
| 5 | 26 | 26 | 21 | 23 | 20 | 30 | 42 | 23 | 19 | 19 | 20 | 28 |
| 6 | 26 | 26 | 20 | 23 | 18 | 30 | 42 | 21 | 19 | 19 | 20 | 28 |
| 7 | 26 | 23 | 18 | 23 | 18 | 26 | 46 | 23 | 19 | 19 | 20 | 28 |
| 8 | 26 | 21 | 18 | 23 | 18 | 30 | 51 | 23 | 19 | 19 | 19 | 28 |
| 9 | 23 | 20 | 16 | 20 | 19 | 34 | 51 | 26 | 19 | 19 | 19 | 28 |
| 10 | 20 | 20 | 16 | 20 | 19 | 34 | 51 | 26 | 19 | 19 | 19 | 27 |
| 11 | 20 | 20 | 18 | 19 | 19 | 39 | 51 | 23 | 19 | 19 | 19 | 27 |
| 12 | 20 | 23 | 18 | 19 | 20 | 56 | 51 | 21 | 19 | 19 | 19 | 27 |
| 13 | 20 | 23 | 26 | 19 | 20 | 56 | 51 | 21 | 19 | 19 | 19 | 27 |
| 14 | 20 | 23 | 21 | 18 | 20 | 59 | 51 | 20 | 18 | 19 | 20 | 27 |
| 15 | 20 | 23 | 21 | 18 | 20 | 68 | 51 | 20 | 18 | 19 | 20 | 27 |
| 16 | 21 | 24 | 23 | 18 | 20 | 68 | 46 | 18 | 18 | 19 | 20 | 27 |
| 17 | 23 | 26 | 24 | 17 | 34 | 71 | 42 | 18 | 18 | 20 | 20 | 27 |
| 18 | 23 | 23 | 24 | 16 | 44 | 74 | 38 | 18 | 18 | 20 | 20 | 27 |
| 19 | 24 | 23 | 23 | 16 | 44 | 81 | 33 | 18 | 19 | 20 | 20 | 27 |
| 20 | 24 | 23 | 23 | 14 | 44 | 78 | 33 | 18 | 19 | 20 | 20 | 27 |
| 21 | 34 | 23 | 21 | 14 | 39 | 74 | 33 | 18 | 19 | 20 | 20 | 26 |
| 22 | 34 | 23 | 21 | 14 | 39 | 68 | 31 | 18 | 20 | 20 | 21 | 26 |
| 23 | 30 | 23 | 20 | 14 | 36 | 68 | 31 | 18 | 20 | 20 | 22 | 26 |
| 24 | 30 | 24 | 21 | 16 | 36 | 62 | 30 | 17 | 20 | 20 | 23 | 24 |
| 25 | 26 | 24 | 23 | 17 | 34 | 62 | 30 | 17 | 20 | 20 | 24 | 24 |
| 26 | 23 | 24 | 23 | 17 | 34 | 56 | 26 | 17 | 19 | 20 | 24 | 26 |
| 27 | 23 | 23 | 23 | 17 | 36 | 50 | 26 | 17 | 19 | 19 | 26 | 27 |
| 28 | 23 | 23 | 23 | 18 | 44 | 46 | 23 | 17 | 19 | 19 | 27 | 27 |
| 29 | 23 | ..... | 23 | 18 | 39 | 44 | 21 | 17 | 19 | 19 | 27 | 27 |
| 30 | 20 | ..... | 23 | 19 | 39 | 42 | 21 | 18 | 19 | 19 | 26 | 27 |
| 31 | 20 | ..... | 23 | ..... | 36 | ..... | 26 | 18 | ..... | 19 | ..... | 26 |

NOTE.—Owing to shifting conditions, the daily discharge has been computed from several curves, each covering a short period of time.

*Estimated monthly discharge of Rock Creek near Round Valley, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 34 | 20 | 24.8 | 1,525 |
| February | 56 | 20 | 24.9 | 1,383 |
| March | 26 | 16 | 21.5 | 1,322 |
| April | 23 | 14 | 18.7 | 1,113 |
| May | 44 | 18 | 28.8 | 1,771 |
| June | 81 | 26 | 51.1 | 3,041 |
| July | 51 | 21 | 38.5 | 2,367 |
| August | 26 | 17 | 20.1 | 1,236 |
| September | 20 | 18 | 19.0 | 1,131 |
| October | 20 | 19 | 19.3 | 1,187 |
| November | 27 | 19 | 21.1 | 1,256 |
| December | 28 | 24 | 26.9 | 1,654 |
| The year | 81 | 14 | 26.2 | 18,990 |

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### PINE CREEK NEAR ROUND VALLEY, CAL.

This station was established August 3, 1903, by J. C. Clausen. It is located 150 feet below the wagon bridge on the road from Bishop to Long Valley and 100 feet above the mouth of the creek.

The channel is straight for about 50 feet above and 100 feet below the station. The current has a velocity of about 1 foot per second at ordinary stages. Both banks are high and rocky and are not liable to overflow. The bed of the stream is rocky and permanent.

Discharge measurements are made by wading. The initial point for soundings is a stake on the right bank of the stream.

The gage is a vertical rod fastened in the rocks near the right bank. During 1905 the gage was read once each day by T. E. Jones. The bench mark is the one at the Rock Creek station. It is a point marked on the lava rock 15 feet east of the left end of the footbridge.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 208; 134, p 207.
Discharge: 100, p 209; 134, p 208.
Discharge, monthly: 134, p 210.
Gage heights: 100, p 209; 134, pp 208-209.
Rating table: 134, p 210.

*Discharge measurements of Pine Creek near Round Valley, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 16 | R. J. Taylor | 20 | 15.2 | 0.88 | 1.91 | 13.3 |
| February 9 | do | 20 | 15.2 | .67 | 1.86 | 10.2 |
| April 4 | J. S. Evans | 8 | 10.4 | .19 | 1.80 | 2.0 |
| April 25 | do | 10 | 8.8 | .66 | 1.70 | 5.8 |
| June 27 | do | 27 | 2.8 | 2.61 | 2.90 | 73 |
| July 25 | do | 19 | 16.1 | 1.43 | 2.05 | 23 |
| August 15 | do | 18 | 10.8 | .67 | 1.80 | 7.2 |
| September 8 | do | 17 | 9.2 | .73 | 1.75 | 6.7 |
| September 27 | do | 17 | 8.1 | .77 | 1.78 | 6.2 |
| November 2 | F. R. S. Buttemer | 17 | 19.7 | .44 | 1.83 | 8.7 |
| November 24 | do | 18 | 18.2 | .42 | 1.85 | 7.7 |
| December 10 | do | 18 | 18.4 | .41 | 1.82 | 7.6 |

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*Daily gage height, in feet, of Pine Creek near Round Valley, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.2 | 2.2 | 1.8 | 1.8 | 1.8 | 1.9 | 2.9 | 1.8 | 1.7 | 1.8 | 1.8 | 1.8 |
| 2 | 2.15 | 2.0 | 1.8 | 1.8 | 1.8 | 1.9 | 2.9 | 1.7 | 1.7 | 1.8 | 1.8 | 1.8 |
| 3 | 2.1 | 2.0 | 1.8 | 1.8 | 1.75 | 1.9 | 2.85 | 1.7 | 1.7 | 1.8 | 1.8 | 1.9 |
| 4 | 1.95 | 1.9 | 1.8 | 1.8 | 1.75 | 1.9 | 2.8 | 1.7 | 1.7 | 1.85 | 1.8 | 1.9 |
| 5 | 1.95 | 1.9 | 1.8 | 1.8 | 1.75 | 1.95 | 2.8 | 1.7 | 1.7 | 1.85 | 1.85 | 1.9 |
| 6 | 1.95 | 1.8 | 1.8 | 1.8 | 1.7 | 1.95 | 2.8 | 1.7 | 1.7 | 1.85 | 1.85 | 1.9 |
| 7 | 1.9 | 1.8 | 1.8 | 1.75 | 1.7 | 2.05 | 2.9 | 1.7 | 1.7 | 1.85 | 1.85 | 1.9 |
| 8 | 1.9 | 1.85 | 1.8 | 1.75 | 1.7 | 2.1 | 2.95 | 1.7 | 1.65 | 1.85 | 1.85 | 1.9 |
| 9 | 1.9 | 1.85 | 1.8 | 1.75 | 1.7 | 2.45 | 3.0 | 1.8 | 1.6 | 1.85 | 1.8 | 1.9 |
| 10 | 1.8 | 1.85 | 1.75 | 1.75 | 1.7 | 2.7 | 3.0 | 1.8 | 1.65 | 1.8 | 1.8 | 1.8 |
| 11 | 1.8 | 1.85 | 1.75 | 1.8 | 1.75 | 2.6 | 2.9 | 1.75 | 1.65 | 1.8 | 1.8 | 1.8 |
| 12 | 1.8 | 1.85 | 1.8 | 1.8 | 1.8 | 2.8 | 2.85 | 1.7 | 1.65 | 1.7 | 1.8 | 1.8 |
| 13 | 1.75 | 1.85 | 1.8 | 1.8 | 1.8 | 3.3 | 2.8 | 1.7 | 1.65 | 1.75 | 1.8 | 1.8 |
| 14 | 1.75 | 1.85 | 1.8 | 1.8 | 1.8 | 3.3 | 2.7 | 1.7 | 1.65 | 1.75 | 1.8 | 1.8 |
| 15 | 1.75 | 1.85 | 1.8 | 1.8 | 1.75 | 3.3 | 2.6 | 1.7 | 1.6 | 1.8 | 1.8 | 1.8 |
| 16 | 1.8 | 1.8 | 1.85 | 1.8 | 1.75 | 3.3 | 2.5 | 1.7 | 1.6 | 1.8 | 1.8 | 1.8 |
| 17 | 1.8 | 1.8 | 1.85 | 1.8 | 1.75 | 3.25 | 2.4 | 1.7 | 1.65 | 1.8 | 1.8 | 1.8 |
| 18 | 1.8 | 1.85 | 1.85 | 1.75 | 1.75 | 3.2 | 2.45 | 1.75 | 1.65 | 1.85 | 1.8 | 1.8 |
| 19 | 1.8 | 1.85 | 1.8 | 1.75 | 1.75 | 3.2 | 2.5 | 1.75 | 1.7 | 1.85 | 1.8 | 1.8 |
| 20 | 1.85 | 1.8 | 1.8 | 1.75 | 1.8 | 3.1 | 2.5 | 1.75 | 1.7 | 1.85 | 1.8 | 1.8 |
| 21 | 2.0 | 1.8 | 1.8 | 1.75 | 1.9 | 3.1 | 2.1 | 1.75 | 1.75 | 1.85 | 1.8 | 1.8 |
| 22 | 2.0 | 1.8 | 1.8 | 1.7 | 1.9 | 3.1 | 1.95 | 1.75 | 1.8 | 1.85 | 1.8 | 1.8 |
| 23 | 1.9 | 1.8 | 1.8 | 1.7 | 1.9 | 3.0 | 1.95 | 1.75 | 1.8 | 1.85 | 1.8 | 1.8 |
| 24 | 1.9 | 1.8 | 1.8 | 1.7 | 2.0 | 2.9 | 2.0 | 1.7 | 1.8 | 1.85 | 1.85 | 1.8 |
| 25 | 1.9 | 1.85 | 1.8 | 1.7 | 2.0 | 2.9 | 2.0 | 1.7 | 1.8 | 1.85 | 1.85 | 1.8 |
| 26 | 1.9 | 1.85 | 1.8 | 1.7 | 2.0 | 2.9 | 2.0 | 1.7 | 1.8 | 1.85 | 1.85 | 1.8 |
| 27 | 1.9 | 1.8 | 1.8 | 1.7 | 2.0 | 2.9 | 2.05 | 1.7 | 1.8 | 1.8 | 1.85 | 1.8 |
| 28 | 1.9 | 1.8 | 1.75 | 1.75 | 1.95 | 2.9 | 2.05 | 1.7 | 1.8 | 1.8 | 1.8 | 1.8 |
| 29 | 1.9 | ..... | 1.75 | 1.75 | 1.9 | 2.9 | 2.0 | 1.7 | 1.8 | 1.8 | 1.8 | 1.8 |
| 30 | 1.85 | ..... | 1.75 | 1.75 | 1.8 | 2.9 | 2.0 | 1.7 | 1.8 | 1.8 | 1.8 | 1.8 |
| 31 | 1.85 | ..... | 1.8 | ..... | 1.85 | ..... | 1.9 | 1.7 | ..... | 1.8 | ..... | 1.8 |

*Station rating table for Pine Creek near Round Valley, Cal., from August 4, 1903, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.60 | 1 | 2.10 | 23 | 2.60 | 52 | 3.10 | 95 |
| 1.70 | 4 | 2.20 | 28 | 2.70 | 59 | 3.20 | 106 |
| 1.80 | 8 | 2.30 | 33 | 2.80 | 67 | 3.30 | 119 |
| 1.90 | 13 | 2.40 | 39 | 2.90 | 75 | | |
| 2.00 | 18 | 2.50 | 45 | 3.00 | 85 | | |

NOTE.—The above table is based on 20 discharge measurements made during 1903–1905. It is fairly well defined between gage heights 1.7 feet and 3 feet. The table has been extended beyond these limits, being based on one measurement at 3.7 feet.

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*Estimated monthly discharge of Pine Creek near Round Valley, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 28 | 6 | 12.7 | 781 |
| February | 28 | 8 | 10.6 | 589 |
| March | 10 | 6 | 7.9 | 486 |
| April | 8 | 4 | 6.5 | 387 |
| May | 18 | 4 | 9.0 | 553 |
| June | 119 | 13 | 68.1 | 4,052 |
| July | 85 | 13 | 47.9 | 2,945 |
| August | 8 | 4 | 4.8 | 295 |
| September | 8 | 1 | 4.6 | 274 |
| October | 10 | 4 | 8.7 | 535 |
| November | 10 | 8 | 8.5 | 506 |
| December | 13 | 8 | 9.5 | 584 |
| The year | 119 | 1 | 16.6 | 11,990 |

### OWENS RIVER CANAL NEAR BISHOP, CAL.

This station was established August 5, 1903, by J. C. Clausen and R. S. Hawley. It is located at the footbridge near the quarter-section line which divides the north half of sec. 27, T 6 S., R. 32 E., of the Mount Diablo meridian.

The channel is straight for 300 feet above and 100 feet below the station. The current is sluggish. The right bank is high and rocky and will not overflow. The left bank is low and will overflow. The bed of the stream is composed of gravel and is permanent.

Discharge measurements are made from the footbridge. The initial point for soundings is on right bank of the canal.

The gage is a vertical rod nailed to the bridge. No regular observer could be obtained, but the ditch tender reads the rod when passing the station.

Information in regard to this station is contained in the following Water-Supply Paper of the United States Geological Survey:

Description: 100, pp 209–210; 134, p 211.
Discharge: 100, p 210; 134, p 211.
Discharge, monthly: 134, p 213.
Gage heights: 100, p 210; 134, p 212.
Rating table: 134, p 213.

*Discharge measurements of Owens River Canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 10 | R. J. Taylor | 11.5 | 4.9 | 0.92 | 1.55 | 4.5 |
| February 4 | do | 11 | 4.1 | .80 | 1.49 | 3.3 |
| April 6 | J. S. Evans | 14.5 | 16.4 | 1.71 | 2.40 | 28 |
| April 24 | do | 15.0 | 22 | 1.91 | 2.77 | 42 |
| May 12 | do | 14.5 | 24 | 1.79 | 2.78 | 43 |
| June 1 | do | 14.5 | 21 | 1.76 | 2.62 | 38 |
| July 7 | do | 14 | 16.8 | 1.90 | 2.30 | 32 |
| August 4 | do | 14.5 | 23 | 1.87 | 2.75 | 43 |
| September 11 | do | 15 | 19.6 | 1.73 | 2.60 | 34 |
| October 24 | F. R. S. Buttemer | 14.5 | 19.3 | 1.45 | 2.38 | 28 |
| November 22 | do | 12 | 5.6 | .95 | 1.50 | 5.3 |
| December 13 | do | 13 | 6.6 | 1.17 | 1.63 | 7.7 |



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*Daily gage height, in feet, of Owens River canal near Bishop, Cal., for 1905.*

| Day. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|
| 1 | ..... | 0.0 | 2.7 | 2.55 | 2.8 | 2.55 | 2.8 |
| 2 | ..... | .0 | 2.7 | 2.55 | 2.75 | 2.55 | 2.8 |
| 3 | ..... | .0 | 2.7 | 2.55 | 2.8 | 2.55 | 2.8 |
| 4 | ..... | 2.4 | ..... | 2.55 | 2.75 | 2.55 | 2.8 |
| 5 | ..... | 2.7 | 2.65 | 2.55 | 2.8 | 2.55 | 2.8 |
| 6 | ..... | 2.7 | 2.65 | 2.55 | 2.85 | 2.75 | 2.75 |
| 7 | ..... | 2.7 | 2.6 | 2.55 | 2.9 | 2.8 | 2.75 |
| 8 | ..... | 2.65 | 2.6 | 2.55 | 2.85 | 2.8 | 2.8 |
| 9 | ..... | 2.7 | ..... | 2.55 | 2.85 | 2.8 | 2.8 |
| 10 | ..... | 2.5 | ..... | 2.55 | 2.9 | 2.8 | 2.8 |
| 11 | ..... | 2.7 | 2.65 | 2.55 | 2.9 | 2.75 | 2.7 |
| 12 | ..... | 2.8 | 2.7 | 2.55 | 2.5 | 2.8 | 2.7 |
| 13 | ..... | 2.8 | 2.65 | 2.55 | 2.5 | 2.8 | 2.7 |
| 14 | ..... | ..... | 2.7 | 2.55 | 2.5 | 2.8 | 2.75 |
| 15 | ..... | 2.75 | 2.55 | 2.55 | 2.5 | 2.75 | ..... |
| 16 | ..... | 2.8 | 2.55 | 2.55 | 2.5 | 2.8 | ..... |
| 17 | ..... | 2.75 | 2.55 | 2.5 | .0 | 2.75 | ..... |
| 18 | ..... | 2.75 | 2.55 | 2.65 | .0 | 2.6 | ..... |
| 19 | ..... | 2.7 | 2.5 | 2.7 | .0 | 2.6 | ..... |
| 20 | ..... | 2.75 | 2.5 | 2.7 | 2.6 | 2.6 | ..... |
| 21 | ..... | 2.75 | 2.5 | 2.65 | 2.6 | 2.6 | ..... |
| 22 | ..... | 2.7 | 2.55 | 2.65 | .0 | 2.6 | ..... |
| 23 | ..... | 2.65 | 2.55 | 2.7 | .0 | 2.6 | ..... |
| 24 | ..... | 2.65 | 2.55 | 2.7 | 2.6 | 2.6 | ..... |
| 25 | ..... | 2.7 | 2.55 | 2.7 | 2.6 | 2.65 | ..... |
| 26 | 2.8 | 2.7 | 2.55 | 2.7 | 2.8 | 2.65 | ..... |
| 27 | 2.8 | 2.75 | 2.55 | 2.7 | 2.85 | 2.7 | ..... |
| 28 | ..... | ..... | 2.55 | 2.75 | 2.85 | 2.65 | ..... |
| 29 | ..... | ..... | 2.55 | 2.7 | 2.9 | 2.5 | ..... |
| 30 | 2.65 | 2.7 | 2.55 | 2.8 | 2.95 | 2.8 | ..... |
| 31 | ..... | 2.7 | ..... | 2.75 | 2.55 | ..... | ..... |

### BISHOP CREEK CANAL NEAR BISHOP, CAL.

This station was established August 5, 1903, by J. C. Clausen, assisted by R. S. Hawley. It is located at the footbridge below the waste gate near the house of A. Fitzgerald, 3½ miles northwest of Bishop, Cal.

The channel is straight for 50 feet above and 100 feet below this station. The current is swift. The right bank is high and the left bank is low. Neither bank is liable to overflow. The bed of the stream is composed of sand and gravel and is fairly permanent.

Discharge measurements are made from the footbridge. The initial point for soundings is on right bank.

The gage is a vertical rod fastened to the bridge anchor.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 210–211; 134, p 214.
Discharge: 100, p 211; 134, p 214.
Discharge, monthly: 134, p 216.
Gage heights: 100, p 211; 134, p 215.
Rating table: 134, p 216.

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*Discharge measurements of Bishop Creek canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 17 | R. J. Taylor | 15 | 10.1 | 0.84 | 1.40 | 8.5 |
| April 6 | J. S. Evans | 16 | 30 | 2.07 | 2.80 | 62 |
| April 24 | do | 16 | 47 | 2.23 | 3.81 | 105 |
| May 12 | do | 16 | 49 | 2.20 | 3.95 | 108 |
| June 1 | do | 16 | 50 | 2.08 | 4.00 | 105 |
| July 7 | do | 16 | 44 | 1.75 | 3.70 | 77 |
| August 4 | do | 16 | 51 | 2.39 | 4.10 | 122 |
| September 11 | do | 16 | 44 | 2.20 | 3.85 | 97 |
| October 24 | F. R. S. Buttemer | 16 | 26 | 1.12 | 1.92 | 29 |
| November 22 | do | 13 | 4.6 | .39 | 1.05 | 1.8 |
| December 13 | do | 13 | 5.1 | .31 | 1.06 | 1.6 |
| December 21 | do | 14 | 15.6 | .79 | 1.21 | 12.4 |

*Daily gage height, in feet, of Bishop Creek canal near Bishop, Cal., for 1905.*

| Day. | Aug. | Sept. | Day. | Aug. | Sept. | Day. | Aug. | Sept. | Day. | Aug. | Sept |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | 9 | 3.9 | 3.5 | 17 | 3.5 | 2.9 | 25 | 4.0 | |
| 2 | | | 10 | 3.5 | 3.5 | 18 | 3.5 | 2.9 | 26 | 4.0 | |
| 3 | | 4.0 | 11 | 3.5 | 3.5 | 19 | 3.5 | 2.9 | 27 | | |
| 4 | | 4.0 | 12 | 3.5 | 3.5 | 20 | 3.5 | 2.9 | 28 | | |
| 5 | | 4.0 | 13 | 3.5 | 3.5 | 21 | | 2.9 | 29 | | |
| 6 | 3.9 | 3.5 | 14 | 3.5 | 3.5 | 22 | 3.5 | 2.9 | 30 | | |
| 7 | 3.9 | 3.5 | 15 | 3.5 | 3.5 | 23 | | 2.9 | 31 | | |
| 8 | 3.9 | 3.5 | 16 | 3.5 | 3.5 | 24 | 3.5 | | | | |

### FARMERS' CANAL NEAR BISHOP, CAL.

This station was established August 6, 1903, by J. C. Clausen and R. S. Hawley. It is located at the footbridge near the house of Robert Love and 3 miles north of Bishop, Cal.

The channel is straight for 300 feet above and 50 feet below the station. The current is sluggish. Both banks are low and are liable to overflow. The bed of the stream is sandy and shifting.

Discharge measurements are made from the footbridge, to which the gage is attached. The initial point for soundings is on the footbridge, near the right bank.

The gage is a vertical rod fastened to the bridge pier.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 211-212; 134, p 216.
Discharge: 100, p 212; 134, p 217.
Discharge, monthly: 134, p 219.
Gage heights: 100, p 212; 134, pp 217-218.
Rating table: 134, p 219.

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*Discharge measurements of Farmers' canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 10 | R. J. Taylor | 13 | 9.0 | 0.69 | 2.20 | 6.2 |
| February 4 | do | 13 | 9.4 | .74 | 2.16 | 7.0 |
| March 7 | do | 10 | 16.8 | 1.79 | 2.90 | 30 |
| April 6 | J. S. Evans | 10.5 | 12.8 | 1.47 | 2.55 | 18.8 |
| April 24 | do | 10 | 8.4 | .64 | 2.30 | 5.4 |
| May 12 | do | 10.5 | 12.8 | 1.16 | 2.60 | 14.9 |
| June 1 | do | 10.5 | 14.6 | 1.37 | 2.60 | 20 |
| July 7 | do | 9.5 | 15.4 | 1.56 | 2.75 | 24 |
| August 4 | do | 10 | 9.0 | .53 | 2.00 | 4.8 |
| September 11 | do | 10.5 | 15.7 | 1.04 | 2.55 | 16.4 |
| November 22 | F. R. S. Buttemer | 10.5 | 10.8 | .70 | 2.35 | 7.6 |
| December 13 | do | 10.5 | 10.8 | .59 | 2.36 | 6.4 |

*Daily gage height, in feet, of Farmers' canal near Bishop, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | 2.5 |
| 2 | | | | | 2.8 | 2.7 | | |
| 3 | 2.2 | 2.15 | 3.0 | | | | 2.6 | |
| 4 | | 2.16 | | 2.65 | | | | 2.5 |
| 5 | | | 2.9 | | 2.8 | | | |
| 6 | 2.2 | | | 2.55 | | 2.7 | | |
| 7 | | | 2.9 | | | | 2.75 | |
| 8 | | | | | | | | 2.6 |
| 9 | 2.2 | | 2.9 | | 2.6 | 2.75 | | |
| 10 | 2.2 | | | | | | | |
| 11 | | 2.15 | | 1.8 | | | | 2.6 |
| 12 | | | | | 2.6 | | 2.7 | |
| 13 | | | | | 2.6 | 2.9 | | |
| 14 | 2.2 | 2.15 | 3.0 | 1.7 | | | 2.65 | |
| 15 | | | | | | | | 2.65 |
| 16 | | | | | 2.65 | 2.95 | | |
| 17 | 2.15 | | 2.9 | | | | | |
| 18 | | | | 1.1 | | | 2.6 | 2.55 |
| 19 | | | | | 2.95 | | | |
| 20 | 2.15 | | | | | 2.8 | | |
| 21 | | | | | | | 2.6 | 2.2 |
| 22 | | | | 1.2 | | | | |
| 23 | | | 2.75 | | 2.95 | 2.7 | | |
| 24 | | | | 2.3 | | | | |
| 25 | 2.15 | | | 2.3 | | | 2.6 | 2.65 |
| 26 | | | | | 2.9 | | | 2.65 |
| 27 | | | | | | 2.7 | | |
| 28 | 2.15 | | 2.75 | 2.7 | | | 2.55 | |
| 29 | | | | | | | | |
| 30 | | | | | 2.9 | 2.6 | | |
| 31 | 2.15 | | 2.75 | | | | | |

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### McNALLY CANAL NEAR BISHOP, CAL.

This station was established July 31, 1903, by J. C. Clausen and R. S. Hawley. It is located at the head of the canal, 3¼ miles north of Bishop, Cal.

The channel is straight for 50 feet below the gage. The current is swift. Both banks are high and will not overflow. The bed of the stream is rocky and permanent.

Discharge measurements are made from a footbridge. The initial point for soundings is marked on the footbridge, near the right bank.

The gage is a vertical board fastened to the headworks of the canal. No gage reader could be obtained for this station, but since the gage was installed there has been little variation in the amount of water flowing in the canal.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 213; 134, pp 219–220.
Discharge: 100, p 213; 134, p 220.
Discharge, monthly: 134, p 221.
Gage heights: 134, pp 220–221.
Rating table: 134, p 221.

*Discharge measurements of McNally canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 17 | R. J. Taylor | 20 | 11.2 | 1.06 | 0.50 | 11.9 |
| April 6 | J. S. Evans | 20 | 14.2 | 1.76 | .70 | 25 |
| April 24 | do | 21 | 18.2 | 2.09 | 1.00 | 38 |
| May 12 | do | 21 | 21 | 2.05 | 1.05 | 43 |
| June 1 | do | 21 | 25 | 2.23 | 1.10 | 56 |
| July 7 | do | 22 | 32 | 2.69 | 1.30 | 86 |
| August 4 | do | 22 | 32 | 1.66 | 1.50 | 53 |
| September 11 | do | 21 | 23 | 2.17 | 1.10 | 50 |
| November 22 | F. R. S. Buttemer | 21 | 17.5 | 1.14 | .70 | 20 |
| December 13[a] | do | | | | .10 | 0 |

[a] Headgate shut down; no water in canal.

### GEORGE COLLINS CANAL NEAR BISHOP, CAL.

This station was established August 17, 1903, by R. S. Hawley. It is located at the footbridge 3 miles east and one-half mile north of Bishop, Cal.

The channel is straight for 75 feet above and for 50 feet below the station. The current is sluggish. The right bank is low and the left bank is high. Neither bank is liable to overflow. The bed of the stream is composed of sand and is fairly permanent.

Discharge measurements are made from the bridge. The initial point for soundings is marked on the footbridge near the right bank of the canal.

The gage is a vertical rod fastened to the bridge near the house of Arthur Wines.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 213; 134, p 222.
Discharge: 100, p 214; 134, p 222.
Discharge, monthly: 134, p 225.
Gage heights: 100, p 214; 134, pp 223–224.
Rating table: 134, p 224.

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*Discharge measurements of George Collins canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| May 2 | J. S. Evans | 11 | 10.8 | 1.12 | 1.10 | 12.1 |
| May 25 | do | 14 | 13 | 1.13 | 1.35 | 14 |
| June 28 | do | 11.5 | 7.3 | .71 | 1.00 | 5.2 |
| July 26 | do | 11.5 | 9.1 | .65 | 1.00 | 5.9 |
| August 9 | do | 11.5 | 8.0 | .50 | .60 | 4.0 |
| September 5 | do | 12 | 8.4 | .57 | .60 | 4.8 |
| September 14 | do | 11.6 | 8.0 | .65 | .50 | 5.2 |
| October 3 | do | 12 | 8.8 | 1.00 | .65 | 8.8 |
| October 25 | F. R. S. Buttemer | 11 | 5.8 | .59 | .78 | 3.4 |
| November 23 | do | 11.5 | 5.2 | .65 | .82 | 3.4 |
| December 11 | do | 10.7 | 4.7 | .53 | .80 | 2.5 |

*Daily gage height, in feet, of George Collins canal near Bishop, Cal., for 1905.*

| Day. | May. | June. | July. | Aug. | Sept. | Oct. | Day. | May. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0.9 | | 0.8 | | 1.0 | 17 | 1.0 | 1.4 | 1.2 | 0.9 | | |
| 2 | 0.9 | 1.0 | | .8 | 0.8 | .9 | 18 | 1.0 | 1.5 | | .9 | 1.2 | |
| 3 | | 1.0 | 0.8 | | .8 | | 19 | 1.0 | 1.4 | | | | |
| 4 | .9 | | | | | .9 | 20 | 1.0 | | 1.0 | | 1.2 | |
| 5 | | 1.0 | | .5 | .8 | | 21 | | 1.0 | | .9 | 1.1 | |
| 6 | | 1.0 | .8 | | | .9 | 22 | 1.0 | 1.0 | 1.0 | | | |
| 7 | 1.0 | 1.2 | .9 | .5 | .9 | | 23 | | | | .8 | 1.1 | |
| 8 | | 1.5 | | | | | 24 | 1.0 | .9 | | .8 | 1.1 | |
| 9 | .8 | 1.5 | 1.4 | .5 | 1.2 | | 25 | | .9 | | | | |
| 10 | | 1.4 | | .5 | | | 26 | | 1.0 | .9 | | 1.0 | |
| 11 | .8 | .8 | 1.4 | | 1.2 | | 27 | .6 | | | .9 | | |
| 12 | | 1.5 | 1.4 | | 1.2 | | 28 | .5 | | | | 1.0 | |
| 13 | | 1.6 | | .8 | | | 29 | .5 | .8 | .9 | .9 | | |
| 14 | .8 | 1.6 | 1.4 | .9 | | | 30 | .6 | .8 | | .9 | | |
| 15 | 1.0 | 1.4 | | | 1.2 | | 31 | | | | | | |
| 16 | 1.0 | 1.4 | 1.2 | | | | | | | | | | |

NOTE.—Water shut off October 6 to December 31.

### BISHOP CREEK NEAR BISHOP, CAL.

This station was established August 10, 1903, by J. C. Clausen and R. S. Hawley. It is located at the wagon bridge on the Bishop road about 4¼ miles from Bishop and about 2 miles from the point where the creek leaves the canyon. North Hillside canal, South Hillside canal, and Powers canal are taken out above the station.

The channel is straight for 100 feet above and for 50 feet below the station. The current is swift. Both banks are high and rocky and are not liable to overflow. The bed of the stream is rough and rocky and is permanent.

Discharge measurements are made from the wagon bridge. The initial point for soundings is marked on the bridge near the right bank of the stream.

The gage is a vertical rod fastened in the rocks and braced to the right bank just above the wagon bridge. During 1905 the gage was read once each day by A. S. Kilpatrick. The bench mark is a large flat granite bowlder on the right bank 40 feet above the bridge.

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Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 214–215; 134, p 225.
Discharge: 100, p 215; 134, p 226.
Discharge, monthly: 134, p 228.
Gage heights: 100, p 215; 134, pp 226–227.
Rating table: 134, p 228.

*Discharge measurements of Bishop Creek near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 11 | R. J Taylor | 16 | 22 | 1.18 | 1.40 | 26 |
| February 8 | do | 16 | 24 | 1.25 | 1.55 | 30 |
| March 4 | do | 16 | 23 | 1.35 | 1.55 | 31 |
| April 3 | J. S. Evans | 16 | 20 | 2.10 | 1.65 | 42 |
| April 18 | do | 16 | 22 | 1.50 | 1.57 | 33 |
| May 5 | do | 16 | 34 | 2.76 | 2.30 | 94 |
| June 21 | do | 19 | 63 | 6.21 | 3.80 | 391 |
| July 10 | do | 18 | 61 | 5.54 | 3.60 | 338 |
| July 27 | do | 17 | 44 | 4.01 | 2.75 | 178 |
| August 10 | do | 16 | 37 | 3.35 | 2.50 | 124 |
| September 7 | do | 16 | 28 | 2.07 | 2.00 | 58 |
| September 22 | do | 16 | 24 | 1.91 | 1.80 | 46 |
| October 25 | F. R. S. Buttemer | 15 | 25 | .84 | 1.35 | 21 |
| November 23 | do | 16 | 19.6 | 1.22 | 1.52 | 24 |
| December 11 | do | 16 | 22 | 1.05 | 1.67 | 23 |
| December 21 | do | 14 | 15.6 | .79 | 1.21 | 12.4 |

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*Daily gage height, in feet, of Bishop Creek near Bishop, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.4 | 1.5 | 1.55 | 1.8 | 2.5 | 2.9 | 3.4 | 2.5 | 2.1 | 1.9 | 1.4 | 1.5 |
| 2 | 1.4 | 1.5 | 1.55 | 1.8 | 2.5 | 2.9 | 3.3 | 2.3 | 2,1 | 1.9 | 1.4 | 1.4 |
| 3 | 1.4 | 1.45 | 1.5 | 1.75 | 2.5 | 2.9 | 3.2 | 2.3 | 2.1 | 1.8 | 1.4 | 1.5 |
| 4 | 1.4 | 1.5 | 1.6 | 1.75 | 2.3 | 2.9 | 3.3 | 2.3 | 2.0 | 1.9 | 1.4 | 1.4 |
| 5 | 1.4 | 1.5 | 1.6 | 1.75 | 2.3 | 3.0 | 3.3 | 2.2 | 2.0 | 1.8 | 1.4 | 1.4 |
| 6 | 1.4 | 1.5 | 1.6 | 1.8 | 2.1 | 3.1 | 3.3 | 2.2 | 1.9 | 1.8 | 1.4 | 1.5 |
| 7 | 1.45 | 1.5 | 1.6 | 1.8 | 2.1 | 3.3 | 3.4 | 2.2 | 1.8 | 1.8 | 1.4 | 1.5 |
| 8 | 1.45 | 1.5 | 1.6 | 1.8 | 2.1 | 3.4 | 3.4 | 2.3 | 1.9 | 1.8 | 1.5 | 1.5 |
| 9 | 1.4 | 1.5 | 1.6 | 1.75 | 2.0 | 3.3 | 3.5 | 2.4 | 1.9 | 1.8 | 1.5 | 1.5 |
| 10 | 1.4 | 1.55 | 1.6 | 1.75 | 2.0 | 3.4 | 3.6 | 2.5 | 1.9 | 1.8 | 1.4 | 1.4 |
| 11 | 1.4 | 1.5 | 1.6 | 1.7 | 2.0 | 3.5 | 3.7 | 2.6 | 1.8 | 1.8 | 1.4 | 1.4 |
| 12 | 1.4 | 1.5 | 1.65 | 1.7 | 2.1 | 3.6 | 3.7 | 2.5 | 1.7 | 1.7 | 1.5 | 1.5 |
| 13 | 1.4 | 1.45 | 1.65 | 1.7 | 2.1 | 3.6 | 3.6 | 2.4 | 1.8 | 1.7 | 1.5 | 1.5 |
| 14 | 1.4 | 1.45 | 1.7 | 1.75 | 2.1 | 3.6 | 3.2 | 2.35 | 1.8 | 1.7 | 1.4 | 1.5 |
| 15 | 1.45 | 1.45 | 1.7 | 1.75 | 2.2 | 3.7 | 3.0 | 2.3 | 1.7 | 1.7 | 1.5 | 1.5 |
| 16 | 1.45 | 1.4 | 1.7 | 1.75 | 2.2 | 3.8 | 2.8 | 2.2 | 1.7 | 1.6 | 1.4 | 1.5 |
| 17 | 1.45 | 1.4 | 1.65 | 1.75 | 2.5 | 3.8 | 2.7 | 2.2 | 1.9 | 1.6 | 1.5 | 1.4 |
| 18 | 1.5 | 1.4 | 1.65 | 1.7 | 2.5 | 3.8 | 2.6 | 2.2 | 1.8 | 1.6 | 1.5 | 1.4 |
| 19 | 1.5 | 1.4 | 1.7 | 1.7 | 2.6 | 3.8 | 2.6 | 2.2 | 1.9 | 1.6 | 1.6 | 1.5 |
| 20 | 1.45 | 1.4 | 1.7 | 1.7 | 2.7 | 3.8 | 2.5 | 2.2 | 1.8 | 1.5 | 1.6 | 1.5 |
| 21 | 1.45 | 1.4 | 1.7 | 1.7 | 2.5 | 3.8 | 2.5 | 2.3 | 1.9 | 1.5 | 1.5 | 1.4 |
| 22 | 1.4 | 1.4 | 1.7 | 1.7 | 2.5 | 3.8 | 2.5 | 2.2 | 1.8 | 1.5 | 1.5 | 1.5 |
| 23 | 1.4 | 1.5 | 1.7 | 1.8 | 2.5 | 3.7 | 2.6 | 2.2 | 1.8 | 1.5 | 1.5 | 1.4 |
| 24 | 1.4 | 1.5 | 1.7 | 1.8 | 2.6 | 3.6 | 2.6 | 2.2 | 1.9 | 1.4 | 1.5 | 1.5 |
| 25 | 1.4 | 1.5 | 1.75 | 2.0 | 2.6 | 3.3 | 2.7 | 2.2 | 1.9 | 1.4 | 1.5 | 1.4 |
| 26 | 1.4 | 1.5 | 1.75 | 2.4 | 2.6 | 3.3 | 2.7 | 2.2 | 1.9 | 1.4 | 1.5 | 1.4 |
| 27 | 1.4 | 1.5 | 1.8 | 2.4 | 2.7 | 3.2 | 2.8 | 2.2 | 1.9 | 1.4 | 1.5 | 1.5 |
| 28 | 1.4 | 1.5 | 1.8 | 2.5 | 2.8 | 3.2 | 2.8 | 2.1 | 1.8 | 1.4 | 1.5 | 1.5 |
| 29 | 1.45 | ..... | 1.8 | 2.5 | 2.8 | 3.2 | 2.7 | 2.1 | 1.8 | 1.4 | 1.6 | 1.6 |
| 30 | 1.45 | ..... | 1.8 | 2.5 | 2.8 | 3.3 | 2.6 | 2.1 | 1.7 | 1.4 | 1.6 | 1.7 |
| 31 | 1.45 | ..... | 1.8 | ..... | 2.8 | ..... | 2.5 | 2.0 | ..... | 1.4 | ..... | 1.6 |

NOTE.—Gage heights interpolated February 17-19.

*Station rating table for Bishop Creek near Bishop, Cal., from January 1 to December 11, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.40 | 21 | 2.10 | 74 | 2.80 | 170 | 3.50 | 314 |
| 1.50 | 27 | 2.20 | 84 | 2.90 | 188 | 3.60 | 339 |
| 1.60 | 33 | 2.30 | 95 | 3.00 | 206 | 3.70 | 365 |
| 1.70 | 40 | 2.40 | 108 | 3.10 | 225 | 3.80 | 391 |
| 1.80 | 48 | 2.50 | 122 | 3.20 | 245 | | |
| 1.90 | 56 | 2.60 | 137 | 3.30 | 267 | | |
| 2.00 | 65 | 2 70 | 153 | 3.40 | 290 | | |

NOTE. –The above table is based on 14 discharge measurements made during 1905 and some older measurements. It is not very well defined. This table does not apply later than December 11, as conditions were changed at the station.

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*Estimated monthly discharge of Bishop Creek near Bishop, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 27 | 21 | 22.5 | 1,384 |
| February | 30 | 21 | 25.2 | 1,400 |
| March | 48 | 27 | 38.2 | 2,349 |
| April | 122 | 40 | 56.6 | 3,368 |
| May | 170 | 65 | 113 | 6,948 |
| June | 391 | 188 | 299 | 17,790 |
| July | 365 | 122 | 215 | 13,220 |
| August | 137 | 65 | 92.1 | 5,663 |
| September | 74 | 40 | 53.6 | 3,189 |
| October | 56 | 21 | 36.1 | 2,220 |
| November | 33 | 21 | 25.6 | 1,523 |
| December 1-11 | 27 | 21 | 24.3 | 530 |
| The period | | | | 59,580 |

### RAWSON CANAL NEAR BISHOP, CAL.

This station was established August 7, 1903, by R. S. Hawley. It is located at the county bridge 2½ miles east of Bishop, Cal.

The channel is straight for 100 feet above and below the station and the current is swift. The right bank is high and the left bank is low. Neither bank is liable to overflow. The bed of the stream is composed of gravel and is permanent.

Discharge measurements are made from the bridge. The initial point for soundings is marked on the bridge near the right bank of the canal.

The gage is a vertical rod fastened to the bridge. During 1905 the gage was read by W. P. Parker.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 215–216; 134, p 229.
Discharge: 100, p 216; 134, p 229.
Discharge, monthly: 134, p 231.
Gage heights: 100, p 216; 134, pp 230–231.
Rating table: 134, p 231.

*Discharge measurements of Rawson canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sc.* | *Feet.* | *Sec.-ft.* |
| March 14 | R. J. Taylor | 17 | 13.2 | 1.67 | 1.75 | 22 |
| April 1 | J. S. Evans | 17 | 13.3 | 1.95 | 1.85 | 26 |
| April 17 | do | 17 | 10.6 | 1.59 | 1.60 | 16.9 |
| May 2 | do | 17 | 16.3 | 1.72 | 1.90 | 28 |
| May 25 | do | 17 | 17.4 | 1.55 | 1.90 | 27 |
| June 28 | do | 17 | 14.8 | 1.22 | 1.70 | 18.1 |
| July 26 | do | 14 | 5.4 | .39 | 1.30 | 2.1 |
| August 9 | do | 17 | 14.6 | 1.00 | 1.55 | 14.6 |
| September 5 | do | 16 | 9.8 | .72 | 1.45 | 7.0 |
| September 14 | do | 17 | 10.1 | 1.05 | 1.50 | 10.6 |
| October 3 | do | 17 | 15.2 | 1.17 | 1.90 | 17.8 |
| October 25 | F. R. S. Buttemer | 7 | 4.2 | .29 | 1.05 | 1.2 |
| November 23 | do | 6 | 1.6 | .69 | 1.15 | 1.1 |
| December 11 | do | 7 | 4.2 | .31 | 1.08 | 1.3 |

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*Daily gage height, in feet, of Rawson canal near Bishop, Cal., for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.8 | 1.7 | 1.8 | 0.8 | 0.9 | 1.3 | 1.8 |
| 2 | ..... | ..... | 1.7 | 1.8 | .9 | .9 | ..... | 1.8 |
| 3 | ..... | 1.8 | 1.7 | 1.8 | .9 | .8 | 1.3 | 1.8 |
| 4 | ..... | 1.8 | 1.9 | 1.8 | .9 | .8 | 1.5 | 1.8 |
| 5 | ..... | 1.8 | ..... | 1.7 | .9 | .8 | 1.5 | 1.8 |
| 6 | 1.4 | ..... | 1.9 | 1.9 | .8 | .8 | 1.5 | 1.8 |
| 7 | 1.4 | 1.7 | 1.9 | 1.9 | .8 | .8 | 1.7 | 1.6 |
| 8 | 1.5 | 1.7 | 1.8 | 1.9 | .8 | .8 | 1.7 | 1.4 |
| 9 | 1.5 | ..... | 1.8 | 1.8 | .8 | .8 | 1.7 | 1.4 |
| 10 | 1.6 | 1.7 | 1.8 | 1.8 | .8 | .8 | 1.7 | 1.4 |
| 11 | 1.6 | 1.7 | 1.8 | 1.9 | .7 | .8 | 1.7 | 1.4 |
| 12 | 1.6 | 1.7 | 1.8 | 1.8 | .7 | .8 | 1.7 | 1.6 |
| 13 | 1.8 | ..... | 1.8 | 1.8 | .7 | .9 | 1.6 | 1.6 |
| 14 | 1.8 | 1.7 | 1.8 | 1.7 | .8 | .9 | 1.6 | ..... |
| 15 | ..... | 1.6 | 1.9 | 1.0 | .8 | .0 | 1.6 | ..... |
| 16 | ..... | 1.6 | 1.9 | .9 | .8 | ..... | 1.6 | ..... |
| 17 | ..... | 1.6 | 1.9 | 1.4 | .8 | .9 | 1.6 | ..... |
| 18 | ..... | 1.6 | 1.9 | 1.4 | .8 | .9 | 1.6 | ..... |
| 19 | ..... | 1.6 | 1.9 | ..... | .8 | .9 | 1.6 | ..... |
| 20 | ..... | 1.7 | 1.9 | ..... | .8 | ..... | 1.6 | ..... |
| 21 | ..... | 1.7 | 1.8 | ..... | .8 | .7 | 1.7 | ..... |
| 22 | ..... | 1.7 | 1.9 | .6 | .7 | .7 | 1.7 | ..... |
| 23 | ..... | ..... | 1.9 | .8 | .7 | .7 | ..... | ..... |
| 24 | ..... | 1.7 | 1.8 | .9 | .7 | .7 | 1.7 | ..... |
| 25 | ..... | 1.7 | 1.8 | .9 | .7 | .7 | 1.7 | ..... |
| 26 | ..... | 1.7 | 1.8 | .9 | ..... | 1.3 | 1.7 | ..... |
| 27 | ..... | 1.7 | 1.8 | .8 | ..... | 1.3 | 1.7 | ..... |
| 28 | ..... | 1.7 | 1.8 | .8 | ..... | 1.3 | 1.7 | ..... |
| 29 | ..... | 1.7 | 1.7 | .8 | .9 | ..... | 1.7 | ..... |
| 30 | 1.8 | 1.7 | 1.7 | .8 | .9 | 1.3 | ..... | ..... |
| 31 | 1.8 | ..... | 1.7 | ..... | .9 | ..... | ..... | ..... |

NOTE.—Water shut off January 1 to March 5 and October 14 to December 31.

### A. O. COLLINS CANAL NEAR BISHOP, CAL.

This station was established August 7, 1903, by R. S. Hawley. It is located at the county bridge, 3 miles east of Bishop, Cal.

The channel is straight for 100 feet above and 50 feet below the station. The current is sluggish. Both banks are high and are not liable to overflow. The bed of the stream is sandy and shifting.

Discharge measurements are made from the bridge. The initial point for soundings is marked on the foot log near the right bank of the canal.

The gage is a vertical rod fastened to the right bank just above the bridge, from which discharge measurements are made. During 1905 the gage was read by W. P. Parker.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 216–217; 134, p 232.
Discharge: 100, p 217; 134, p 232.
Discharge, monthly: 134, p 235.
Gage heights: 100, p 217; 134, pp 233–234
Rating table: 134, p 234.

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*Discharge measurements of A. O. Collins canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 14 | R. J. Taylor | 11 | 12.5 | 2.00 | 2.90 | 25 |
| April 1 | J. S. Evans | 8 | 2.8 | .75 | 2.00 | 2.1 |
| May 2 | do | 11.5 | 12.8 | 1.95 | 3.00 | 25 |
| June 28 | do | 10 | 10.8 | 1.70 | 2.75 | 18.4 |
| July 26 | do | 10 | 12.8 | 1.44 | 2.90 | 18.4 |
| August 9 | do | 10 | 8.8 | 1.59 | 2.65 | 14.0 |
| September 5 | do | 10 | 6.0 | 1.22 | 2.38 | 7.3 |
| September 14 | do | 10 | 5.4 | 1.20 | 2.33 | 6.5 |
| October 3 | do | 10 | 10.4 | 1.47 | 2.80 | 15.3 |
| October 25 | F. R. S. Buttemer | | | | | 0 |
| November 23 | do | 10.5 | 7.0 | .70 | 2.25 | 4.9 |
| December 11 | do | 10 | 3.8 | .45 | 1.92 | 1.7 |

*Daily gage height, in feet, of A. O. Collins canal near Bishop, Cal., for 1905.*

| Day. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | 2.6 | 1.8 | 2.5 | 2.5 | 2.4 | 2.5 |
| 2 | | | | 2.6 | 1.8 | 2.5 | 2.0 | | 2.5 |
| 3 | | | | 2,8 | 1.6 | 2.7 | | 2.6 | 2.5 |
| 4 | | | | 3.0 | 1.9 | 2.7 | | 2.6 | 2.2 |
| 5 | | | | | 1.9 | 2.8 | | 2.6 | 2.2 |
| 6 | | | | 3.0 | 1.7 | 2.8 | | 2.6 | 2.2 |
| 7 | | | | 3.0 | 1.7 | 2.8 | | 2.3 | 2.2 |
| 8 | | | | 2.4 | 1.8 | 2.9 | | 2.0 | 2.2 |
| 9 | | | | 2.3 | 1.9 | 2.9 | | 2.0 | 2.2 |
| 10 | | 2.4 | | 2.3 | 1.9 | 3.0 | 2.3 | 2.0 | 2.2 |
| 11 | | 2.4 | | 2.3 | 1.9 | 3.0 | 2.3 | 2.0 | 2.3 |
| 12 | | 2.4 | | 2.3 | 1.9 | 3.0 | 2.3 | 2.0 | 2.3 |
| 13 | | 2.8 | | 2.3 | 2.2 | 3.0 | 2.3 | 2.3 | 2.3 |
| 14 | | 2.8 | | 2.3 | 2.3 | 2.9 | 2.3 | 2.3 | |
| 15 | | 2.8 | | 2.3 | 2.3 | 2.9 | | 2.3 | |
| 16 | | 2.8 | | | 2.4 | 2.9 | | 2.3 | |
| 17 | | 2.8 | | | | 2.9 | 2.3 | 2.9 | |
| 18 | | 2.8 | | | | 2.9 | 2.1 | 2.9 | |
| 19 | | 2.8 | 2.6 | | | 2.8 | 2.1 | 2.9 | |
| 20 | | 2.8 | 2.6 | | | 2.8 | | 2.9 | |
| 21 | | 2.8 | 2.6 | | | 2.8 | 2.1 | 2.9 | |
| 22 | 2.3 | 3.0 | 2.6 | | 2.3 | 2.8 | 2.1 | 2.7 | |
| 23 | | 3.0 | | | 2.3 | 2.7 | 2.0 | | |
| 24 | | 3.0 | 2.5 | | 2.3 | 2.7 | 2.0 | 2.7 | |
| 25 | | 2.7 | 2.5 | | 2.6 | 2.7 | 2.0 | 2.7 | |
| 26 | 2.3 | | 2.5 | | 2.6 | 2.7 | 2.0 | 2.7 | |
| 27 | | | 2.5 | | 2.6 | | 2.0 | 2.5 | |
| 28 | | | 2.6 | | 2.6 | | 2.4 | 2.5 | |
| 29 | | | 2.6 | | 2.6 | 2.7 | | 2.5 | |
| 30 | | | 2.6 | | 2.5 | 2.7 | 2.4 | | |
| 31 | | | | 1.7 | | 2.5 | | | |

NOTE.—No flow on days of missing gage heights.

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### DELL CANAL NEAR BISHOP, CAL.

This station was established August 24, 1903, by R. S. Hawley. It is located at a flume 3 miles from the head gate at a point where the canal crosses a slough in Sanders's field.

The channel is straight for 150 feet above and for 200 feet below the station. The current is sluggish at all times.

Discharge measurements are made from a bridge across the flume. The initial point for soundings is the edge of the flume at the right side.

The gage is a vertical rod fastened to the flume.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 217-218; 134, p 235.
Discharge: 100, p 218; 134, pp 235-236.
Discharge, monthly: 134, p 237.
Gage heights: 100, p 218; 134, pp 236-237.

*Discharge measurements of Dell canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 10 | R. J. Taylor | 7.5 | 10.1 | 2.38 | 1.40 | 24 |
| April 14 | J. S. Evans | 7.6 | 7.6 | 2.16 | 1.20 | 16.4 |
| April 28 | do | 7.6 | 11.8 | 1.95 | 1.35 | 23 |
| May 11 | do | 7.6 | 12.5 | 2.08 | 1.48 | 26 |
| June 26 | do | 7.6 | 11.4 | 1.93 | 1.60 | 22 |
| July 6 | do | 7.6 | 12.2 | 1.97 | 1.70 | 24 |
| August 2 | do | 7.6 | 9.1 | 1.89 | 1.30 | 17.2 |
| September 6 | do | 7.6 | 9.1 | 1.85 | 1.31 | 16.8 |
| September 28 | do | 7.6 | 6.8 | 1.70 | 1.12 | 11.6 |
| October 30 | F. R. S. Buttemer | 7.5 | 9.0 | 1.52 | 1.22 | 13.7 |
| November 18 | do | 7.5 | 9.7 | 1.71 | 1.35 | 16.6 |
| December 5 | do | 7.3 | 4.4 | .68 | .62 | 3.0 |

*Daily gage height, in feet, of Dell canal near Bishop, Cal., for 1905.*

| Day. | Feb. | Mar. | Apr. | Nov. | Dec. | Day. | Feb. | Mar. | Apr. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | 1.3 | | | 17 | | | | | |
| 2 | | 1.4 | | | 0.9 | 18 | | 1.4 | | 1.35 | |
| 3 | | | | | | 19 | | | | | |
| 4 | | 1.4 | | | .8 | 20 | | 1.4 | | 1.3 | |
| 5 | | | | | | 21 | | | | | |
| 6 | | 1.4 | | | .6 | 22 | | 1.4 | | 1.3 | |
| 7 | | | | | | 23 | | | | | |
| 8 | | 1.4 | | | .6 | 24 | | 1.2 | | 1.3 | |
| 9 | | | | | | 25 | | | | | |
| 10 | | 1.4 | | | .6 | 26 | 1.4 | 1.2 | | 1.3 | |
| 11 | | | | | | 27 | | | | | |
| 12 | | 1.4 | | | .8 | 28 | 1.4 | 1.2 | | 1.4 | |
| 13 | | | | | | 29 | | | | | |
| 14 | | 1.4 | | | .8 | 30 | | 1.2 | | 1.35 | |
| 15 | | | | | | 31 | | | | | |
| 16 | | 1.4 | | | .8 | | | | | | |

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### BIG PINE AND OWENS RIVER CANAL NEAR BISHOP, CAL.

This station was established by J. C. Clausen and R. S. Hawley, August 4, 1903. It is located at a footbridge near the house of William Oliver, the observer. It is 7½ miles south and 3 miles east of Bishop, Cal.

The channel is straight for 600 feet above and 300 feet below the station. The current is sluggish. Both banks are high and are not liable to overflow. The bed of the stream is sandy and somewhat shifting.

Discharge measurements are made from the footbridge. The initial point for soundings is marked on the footbridge near the right bank of the canal.

The gage is a vertical rod securely nailed to the footbridge.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 218–219; 134, p 238.
Discharge: 100, p 219; 134, p 238.
Discharge, monthly: 134, p 240.
Gage heights: 100, p 219; 134, pp 238–239.
Rating table: 134, p 240.

*Discharge measurements of Big Pine and Owens River canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 25 | R. J. Taylor | 22 | 11.3 | 0.84 | 1.30 | 9.5 |
| February 13 | do | 22 | 9.5 | .70 | 1.15 | 6.7 |
| April 28 | J. S. Evans | 21 | 12.6 | .85 | 1.30 | 10.7 |
| May 11 | do | 22 | 16 | 1.11 | 1.50 | 17.7 |
| June 26 | do | 22 | 27 | 1.11 | 1.90 | 30 |
| July 6 | do | 22 | 18.8 | 1.05 | 1.75 | 19.6 |
| August 2 | do | 22 | 10.8 | .58 | 1.20 | 6.3 |
| September 6 | do | 16 | 10.0 | .59 | 1.17 | 5.9 |
| September 28 | do | 14 | 7.2 | .36 | 1.10 | 2.6 |
| October 30 | F. R. S. Buttemer | 22 | 41 | 1.00 | 2.53 | 41 |
| November 18 | do | 22 | 17.6 | .85 | 1.42 | 15 |
| December 5 | do | 22 | 18.2 | .89 | 1.45 | 16.2 |

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*Daily gage height, in feet, of Big Pine and Owens River canal near Bishop, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.2 | 1.4 | 1.2 | 1.15 | 1.4 | 2.0 | 1.8 | 1.1 | 1.2 | 1.4 | 2.55 | 1.4 |
| 2 | 1.2 | 1.4 | 1.2 | 1.15 | 1.8 | 1.85 | 1.8 | 1.1 | 1.1 | 1.3 | 2.55 | 1.45 |
| 3 | 1.2 | 1.4 | 1.15 | 1.15 | 1.8 | 1.8 | 1.8 | 1.1 | 1.2 | 1.4 | 2.55 | 1.5 |
| 4 | 1 2 | 1.3 | 1.15 | 1.15 | 1.9 | 1.8 | 1.8 | 1.1 | 1.2 | 1.5 | 2.5 | 1.5 |
| 5 | 1.2 | 1.25 | 1.15 | 1.15 | 1.7 | 1.8 | 1.8 | 1.0 | 1.2 | 1.65 | 2.5 | 1.45 |
| 6 | 1.25 | 1.25 | 1.15 | 1.15 | 1.7 | 1.7 | 1.7 | 1.1 | 1.2 | 1.9 | 2.25 | 1.45 |
| 7 | 1.3 | 1.25 | 1.15 | 1.1 | 1.5 | 1.7 | 1.7 | 1.1 | 1.2 | 1.9 | 2.3 | 1 45 |
| 8 | 1.3 | 1.15 | 1.15 | 1.1 | 1.5 | 1.7 | 2 0 | 1.1 | 1.2 | 1.8 | 2.3 | 1.45 |
| 9 | 1.25 | 1.15 | 1.1 | (a) | 1.6 | 1.95 | 2.05 | 1.2 | 1.2 | 2.0 | 2.3 | 1.45 |
| 10 | 1.25 | 1,2 | 1.1 | (a) | 1.55 | 2.15 | 2.2 | 1.2 | 1.2 | 2.1 | 2.55 | 1.4 |
| 11 | 1.25 | 1.2 | 1.1 | (a) | 1.55 | 2.1 | 2.25 | 1.2 | 1.3 | 2.15 | 1.2 | 1.4 |
| 12 | 1.25 | 1.2 | 1.15 | (a) | 1.5 | 2.3 | 2.35 | 1.2 | 1.3 | 2.2 | 1.2 | 1.4 |
| 13 | 1.25 | 1.2 | 1.5 | (a) | 1.5 | 2.45 | 2.4 | 1.2 | 1.2 | 2.2 | 1.2 | 1.4 |
| 14 | 1.25 | 1 15 | 1.75 | 1.35 | 1.5 | 2.65 | 2.4 | 1.2 | 1.2 | 2.1 | 1.2 | 1.4 |
| 15 | 1.3 | 1.15 | 1.55 | 1.4 | 1.5 | 2.7 | 2.25 | 1.2 | 1.3 | 2.15 | 1.2 | 1.4 |
| 16 | 1.4 | 1.2 | 1.55 | 1.25 | 1.5 | 2.8 | 2.1 | 1.2 | 1.3 | 2.15 | 1.2 | 1.4 |
| 17 | 1.4 | 1.2 | 1.4 | 1.35 | 1.55 | 1.8 | 2.05 | 1.2 | 1.3 | 2.3 | 1.3 | 1.4 |
| 18 | 1.35 | 1.2 | 1.4 | 1.45 | 1.6 | 1.8 | 1.8 | 1.2 | 1.3 | 2.3 | 1.4 | 1.4 |
| 19 | 1.35 | 1.2 | 1.35 | 1.3 | 1.8 | 1.85 | 1.7 | 1.1 | 1.1 | 2.35 | 1.4 | 1.4 |
| 20 | 1.4 | 1.2 | 1.35 | 1.3 | 2.1 | 1.7 | 1.6 | 1.1 | 1.15 | 2.35 | 1.35 | 1.4 |
| 21 | 1.4 | 1.15 | 1.35 | 1.15 | 2.15 | 1.65 | 2.0 | 1.0 | 1.15 | 2.35 | 1.3 | 1.35 |
| 22 | 1.35 | 1.15 | 1.35 | 1.15 | 2.25 | 1.7 | 1.9 | 1.0 | 1.1 | 2.35 | 1.25 | 1.35 |
| 23 | 1.35 | 1.15 | 1.1 | 1.1 | 2.2 | 1.8 | 2.0 | 1.5 | 1.1 | 2.35 | 1.25 | 1.35 |
| 24 | 1.35 | 1.25 | 1.1 | 1.1 | 2.25 | 2.2 | 1.6 | 1.6 | 1.1 | 2.35 | 1.25 | 1.3 |
| 25 | 1.35 | 1.25 | 1.1 | 1.1 | 2.0 | 2.2 | 1.4 | 1.5 | 1.2 | 2.35 | 1.3 | 1.3 |
| 26 | 1.35 | 1.25 | 1.1 | 1.45 | 1.8 | 1.9 | 1.3 | 1.4 | 1.2 | 2.35 | 1.3 | 1.4 |
| 27 | 1.3 | 1.3 | 1.2 | 1.4 | 2.25 | 1.8 | 1.3 | 1.4 | 1.15 | 2.35 | 1.4 | 1.4 |
| 28 | 1.3 | 1.2 | 1.2 | 1.4 | 2.25 | 1.6 | 1.2 | 1.4 | 1.15 | 2.45 | 1.4 | 1.4 |
| 29 | 1.3 | ..... | 1.2 | 1.4 | 2.45 | 1.5 | 1.1 | 1.2 | 1.15 | 2.45 | 1.4 | 1.3 |
| 30 | 1.25 | ..... | 1.1 | 1.4 | 2.4 | 1.8 | 1.1 | 1.3 | 1.15 | 2.5 | 1.4 | 1.3 |
| 31 | 1.25 | ..... | 1.1 | ..... | 2.1 | ..... | 1.1 | 1.3 | ..... | 2.55 | ..... | 1.3 |

a Water shut off April 9–13.

### SANGER CANAL AT ALVORD, CAL.

This station was established August 4, 1903, by J. C. Clausen and R. S. Hawley. It is located at the county road bridge, one-fourth mile east of the Southern Pacific Railroad station at Alvord, Cal.

The channel is straight for 300 feet above and for 100 feet below the station. The current is sluggish. Both banks are low and liable to overflow. The bed of the stream is shifting.

Discharge measurements are made from the bridge. The initial point for soundings is marked on the bridge near the left bank of the canal.

The gage is a vertical rod fastened to the bridge.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 219–220; 134, pp 240–241.
Discharge: 100, p 220; 134, p 241.
Gage heights: 100, p 220; 134, pp 241–242.

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*Discharge measurements of Sanger canal at Alvord, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 7 | R. J. Taylor | 16 | 23 | 0.59 | 2.38 | 13.6 |
| February 18 | do | 16 | 22 | .63 | 2.32 | 13.9 |
| April 14 | J. S. Evans | 16 | 26 | .38 | 2.80 | 9.9 |
| April 26 | do | 16 | 29 | .30 | 2.88 | 8.8 |
| May 19 | do | 16 | 32 | .18 | 3.05 | 5.6 |
| June 9 | do | 16 | 29 | .16 | 2.80 | 4.7 |
| August 17 | do | 16 | 18 | .22 | 2.10 | 4.0 |
| September 13 | do | 16 | 16 | .18 | 2.10 | 2.8 |
| October 30 | F. R. S. Buttemer | 16 | 30 | .44 | 2.82 | 13.2 |
| November 18 | do | 16 | 26 | .39 | 2.60 | 10.2 |

*Daily gage height, in feet, of Sanger canal at Alvord, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | Day. | Jan. | Feb. | Mar. | Apr. | May. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.2 | ..... | 1.2 | 2.7 | 2.9 | 17 | 1.9 | ..... | 2.2 | 2.8 | ..... |
| 2 | ..... | 1.7 | 1.2 | 2.7 | 2.9 | 18 | ..... | 1.3 | 2.2 | 2.8 | 3.5 |
| 3 | 2.1 | ..... | ..... | ..... | ..... | 19 | 1.8 | 1.3 | 2.2 | ..... | ..... |
| 4 | ..... | 1.6 | 1.2 | 2.8 | 2.9 | 20 | ..... | ..... | ..... | 2.8 | 3.5 |
| 5 | 2.1 | 1.6 | 1.2 | ..... | ..... | 21 | 1.8 | 1.3 | 2.4 | ..... | ..... |
| 6 | ..... | ..... | ..... | 2.8 | 3.0 | 22 | 1.8 | ..... | ..... | 2.8 | ..... |
| 7 | 2.1 | 1.5 | 1.2 | ..... | 3.0 | 23 | ..... | 1.3 | 2.4 | ..... | ..... |
| 8 | 2.1 | ..... | ..... | 2.9 | ..... | 24 | 1.8 | ..... | ..... | 2.8 | ..... |
| 9 | ..... | 1.5 | 1.8 | 2.9 | 3.1 | 25 | ..... | 1.3 | 2.4 | ..... | ..... |
| 10 | 2.0 | ..... | ..... | ..... | ..... | 26 | 1.8 | 1.3 | 2.4 | 2.8 | ..... |
| 11 | ..... | 1.4 | 2.0 | 2.9 | 3.3 | 27 | ..... | ..... | ..... | ..... | ..... |
| 12 | 2.0 | 1.4 | 2.1 | ..... | ..... | 28 | 1.7 | 1.2 | 2.6 | 2.8 | ..... |
| 13 | ..... | ..... | ..... | 2.9 | 3.4 | 29 | 1.7 | ..... | ..... | 2.8 | ..... |
| 14 | 1.9 | 1.3 | 2.1 | ..... | 3.4 | 30 | ..... | ..... | 2.7 | 2.8 | ..... |
| 15 | 1.9 | ..... | ..... | 2.8 | ..... | 31 | 1.7 | ..... | 2.7 | ..... | ..... |
| 16 | ..... | 1.3 | 2.2 | 2.8 | 3.4 | | | | | | |

### EAST SIDE CANAL NEAR CITRUS, CAL.

This station was established August 27, 1903, by R. S. Hawley. It is located at the head gate of the canal.

At low stages the meter measurements are made by wading at a point below the head gate. High-stage measurements are made from Southern Pacific Railroad bridge, one-half mile below head gate.

The gage is a vertical rod fastened to the head gate at which discharge measurements are made. During 1905 the gage was read by J. Vaughn.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 220; 134, pp 242–243.
Discharge: 100, p 221; 134, p 243.
Discharge, monthly: 134, p 245.
Gage heights: 100, p 221; 134, pp 243–244.
Rating table: 134, p 245.

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*Discharge measurements of East Side canal near Citrus, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| February 2 | R. J. Taylor | 20 | 21 | 1.48 | 2.30 | 31 |
| May 29 | J. S. Evans | 21 | 28 | 1.14 | 2.60 | 32 |
| August 23 | do | 24 | 35 | .63 | 3.10 | 22 |
| September 20 | do | 21 | 28 | .50 | 3.00 | 14 |
| November 8 | F. R. S. Buttemer | 18 | 27 | .66 | 2.63 | 18 |
| December 3 | do | 11 | 3.7 | 1.30 | 1.90 | 4.8 |

*Daily gage height, in feet, of East Side canal near Citrus, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | 2.5 | | | | 3.0 | | | 2.0 |
| 2 | | | | | | 2.4 | | | | 3.1 | | |
| 3 | | 2.3 | 2.3 | 2.5 | | | 3.4 | | | | 3.0 | |
| 4 | | | | | | | | 3.3 | 3.1 | | | 2.1 |
| 5 | | | | | 2.5 | 2.6 | | | | | | |
| 6 | 2.3 | 2.0 | 2.3 | | | | | | | 3.1 | 2.9 | |
| 7 | | | | 2.5 | | | 3.3 | 3.3 | | | | |
| 8 | | | | | 2.5 | | | | 3.1 | | | 2.1 |
| 9 | 2.4 | | | | | 3.0 | | | | 3.1 | | |
| 10 | | 2.0 | 2.4 | 2.5 | | | 3.3 | | | | 2.9 | |
| 11 | | | | | | | | 3.1 | 3.1 | | | 2.1 |
| 12 | | | | | 2.5 | 3.2 | | | | | | |
| 13 | 2.2 | 2.0 | 2.6 | | | | | | | 3.1 | 2.8 | |
| 14 | | | | 2.6 | | | 3.3 | 3.1 | | | | |
| 15 | | | | | 2.6 | | | | 3.1 | | | 2.1 |
| 16 | 2.3 | | | | | 3.2 | | | | 3.1 | | |
| 17 | | 2.1 | 2.5 | 2.6 | | | 3.2 | | | | 2.8 | |
| 18 | | | | | | | | 3.1 | 3.1 | | | 2.1 |
| 19 | | | | | 2.6 | 3.2 | | | | | | |
| 20 | 2.3 | 2.2 | 2.1 | | | | | | | 3.2 | 2.7 | |
| 21 | | | | 2.6 | | | 3.1 | 3.1 | | | | |
| 22 | | | | | 2.5 | | | | 3.1 | | | 2.1 |
| 23 | 2.2 | | | | | 3.2 | | | | 3.2 | | |
| 24 | | 2.2 | 2.2 | 2.6 | | | 3.2 | | | | 2.6 | |
| 25 | | | | | | | | 3.2 | 3.0 | | | 2.0 |
| 26 | | | | | 2.5 | 3.2 | | | | | | |
| 27 | 2.3 | 2.2 | 2.5 | | | | | | | 3.2 | 2.6 | |
| 28 | | | | 2.5 | | | 3.2 | 3.1 | | | | |
| 29 | | | | | 2.6 | | | | 3.1 | | | 1.9 |
| 30 | 2.3 | | | | | 2.3 | | | | 3.0 | | |
| 31 | | | 2.5 | | | | 3.2 | | | | | |

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### STEVENS CANAL NEAR CITRUS, CAL.

This station was established August 27, 1903, by R. S. Hawley. It is located at the waste gate of the canal, 3½ miles north of Citrus, Cal.

The channel is straight for 300 feet above and 200 feet below the station. The current is sluggish. Both banks are high and are not liable to overflow. The bed of the stream is composed of gravel and earth and is fairly permanent.

Discharge measurements are made by wading. The initial point for soundings is on the right bank of the canal.

The gage is a vertical rod fastened to the waste gate. During 1905 the gage was read by J. Vaughn.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 221; 134, p 245.
Discharge: 100, p 222; 134, p 246.
Discharge, monthly: 134, p 248.
Gage heights: 100, p 222; 134, pp 246-247
Rating table: 134, pp 247-248.

*Discharge measurements of Stevens canal near Citrus, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| May 29 | J. S. Evans | 12 | 29 | 1.28 | 2.70 | 37 |
| August 23 | do | 12 | 26 | .71 | 2.50 | 18.5 |
| September 20 | do | 12 | 25 | .92 | 2.55 | 23 |
| November 8 | F. R. S. Buttemer | 13 | 11.6 | .92 | 1.80 | 10.7 |
| December 3 | do | 11 | 9.6 | .76 | 1.65 | 7.3 |



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*Daily gage height, in feet, of Stevens canal near Citrus, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.6 | 1.9 | ..... | 2.1 | ..... | ..... | ..... | 2.3 | ..... | 2.8 | 2.5 |
| 2 | 1.6 | ..... | ..... | ..... | ..... | 2.8 | ..... | 2.5 | ..... | 2.6 | ..... | ..... |
| 3 | ..... | 1.6 | 1.8 | 1.5 | 2.2 | ..... | 2.8 | ..... | ..... | ..... | 2.8 | ..... |
| 4 | 1.6 | ..... | ..... | ..... | ..... | ..... | ..... | 2.5 | 2.4 | 2.6 | ..... | 1.8 |
| 5 | ..... | ..... | ..... | 1.5 | 2.3 | 2.8 | 2.9 | ..... | ..... | ..... | ..... | ..... |
| 6 | 1.5 | 1.5 | 1.9 | ..... | ..... | ..... | ..... | ..... | 2.4 | 2.6 | 2.8 | 1.8 |
| 7 | ..... | ..... | ..... | 1.5 | ..... | 2.8 | 2.8 | 2.5 | ..... | ..... | ..... | ..... |
| 8 | ..... | 1.5 | 2.3 | ..... | 2.2 | ..... | ..... | ..... | 2.4 | ..... | 2.8 | 1.8 |
| 9 | 1.5 | ..... | ..... | ..... | ..... | 2.8 | ..... | 2.5 | ..... | 2.7 | ..... | ..... |
| 10 | ..... | 1.5 | 2.3 | 1.5 | 2.2 | ..... | 2.9 | ..... | ..... | ..... | 2.8 | ..... |
| 11 | 1.5 | ..... | ..... | ..... | ..... | ..... | ..... | 2.5 | 2.5 | 2.7 | ..... | 1.7 |
| 12 | ..... | ..... | ..... | 1.6 | 2.2 | 2.8 | 2.9 | ..... | ..... | ..... | ..... | ..... |
| 13 | 1.5 | 1.5 | 2.4 | ..... | ..... | ..... | ..... | ..... | 2.5 | 2.7 | 2.8 | 1.7 |
| 14 | ..... | ..... | ..... | 1.6 | ..... | 2.8 | 2.9 | 2.7 | ..... | ..... | ..... | ..... |
| 15 | ..... | 1.5 | 2.5 | ..... | 2.2 | ..... | ..... | ..... | 2.5 | ..... | 2.8 | 1.7 |
| 16 | 1.5 | ..... | ..... | ..... | ..... | 2.9 | ..... | 2.7 | ..... | 2.8 | ..... | ..... |
| 17 | ..... | 1.5 | 2.6 | 1.6 | 2.2 | ..... | 2.8 | ..... | ..... | ..... | 2.8 | ..... |
| 18 | 1.6 | ..... | ..... | ..... | ..... | ..... | ..... | 2.6 | 2.6 | 2.8 | ..... | 1.7 |
| 19 | ..... | ..... | ..... | 1.6 | 2.2 | 2.9 | 2.7 | ..... | ..... | ..... | ..... | ..... |
| 20 | 1.5 | 1.6 | 2.4 | ..... | ..... | ..... | ..... | ..... | 2.6 | 2.8 | 2.6 | 1.7 |
| 21 | ..... | ..... | ..... | 1.6 | ..... | 2.9 | 2.7 | 2 5 | ..... | ..... | ..... | ..... |
| 22 | ..... | 1.6 | 2.0 | ..... | 2.5 | ..... | ..... | ..... | 2.6 | ..... | 2.6 | 1.7 |
| 23 | 1.5 | ..... | ..... | ..... | ..... | 2.9 | ..... | 2.5 | ..... | 2.9 | ..... | ..... |
| 24 | ..... | 2.0 | 1.5 | 1.6 | ..... | ..... | 2.7 | ..... | ..... | ..... | 2.5 | ..... |
| 25 | 1.5 | ..... | ..... | ..... | ..... | ..... | ..... | 2.5 | 2.6 | 2.9 | ..... | 1.7 |
| 26 | ..... | ..... | ..... | 1.5 | 2.6 | 2.9 | 2.8 | ..... | ..... | ..... | ..... | ..... |
| 27 | 1.5 | 1.9 | 1.5 | ..... | ..... | ..... | ..... | ..... | 2.6 | 2.9 | 2.5 | 1.7 |
| 28 | ..... | ..... | ..... | 2.1 | ..... | 2.7 | 2.8 | 2.4 | ..... | ..... | ..... | ..... |
| 29 | ..... | ..... | 1.5 | ..... | 2.7 | ..... | ..... | ..... | 2.5 | ..... | 2.5 | 1.7 |
| 30 | 1.5 | ..... | ..... | ..... | ..... | 2.8 | ..... | 2.4 | ..... | 2.8 | ..... | ..... |
| 31 | ..... | ..... | 1.5 | ..... | 2.8 | ..... | 2.5 | ..... | ..... | ..... | ..... | ..... |

### OWENS RIVER NEAR CITRUS, CAL.

This station was established October 30, 1903, by R. S. Hawley. It is located at the county bridge 4 miles east of Independence, Cal., and 1 mile from the Southern Pacific Railroad station at Citrus, Cal. The station at this point shows the amount of waste water which is discharged into Owens Lake.

The channel is straight for 200 feet above and for 300 feet below the station. The current has a mean velocity of about 2 feet per second at ordinary stages. Both banks are high and are not liable to overflow. The bed of the stream is sandy and is liable to shift.

Discharge measurements are made by means of a cable and car located about 1,500 feet above the bridge. The cable has a span of 120 feet.

The gage is a vertical rod nailed to a pile on the upstream side of the middle pier of the bridge. During 1905 the gage was read by Milton Levy. The bench mark is a copper tack in the floor beam directly over the gage rod; elevation, 13.50 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 222; 134, p 248.
Discharge: 100, p 223; 134, p 249.
Discharge, monthly: 134, p 251.
Gage heights: 100, p 223; 134, pp 249–250.
Rating table: 134, p. 251.

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*Discharge measurements of Owens River near Citrus, Cal., in 1905.*

| Date | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| February 2 | R. J. Taylor | 73 | 176 | 2.21 | 6.00 | 389 |
| May 29 | J. S. Evans | 47 | 40 | 1.52 | 3.60 | 61 |
| July 21 | do | 68 | 68 | 1.84 | 4.30 | 125 |
| August 23 | do | 24 | 15.2 | .80 | 3.00 | 12.1 |
| September 20 | do | 25 | 20 | 1.05 | 3.15 | 12 |
| November 8 | F. R. S. Buttemer | 71 | 91 | 1.98 | 4.65 | 180 |
| December 3 | do | 73 | 131 | 2.21 | 5.20 | 290 |
| December 15 | do | 72 | 128 | 2.20 | 5.30 | 282 |

*Daily gage height, in feet, of Owens River near Citrus, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | 5.85 | | | | 5.6 | | | 3.5 | 4.6 | 5.15 |
| 2 | | 6.0 | | | | | 5.35 | | | 3.45 | 4.65 | 5.2 |
| 3 | | 6.8 | | | | | 5.0 | | | 3.45 | 4.7 | 5.3 |
| 4 | | 6.8 | 5.8 | | | | 5.0 | | | 3.5 | 4.75 | 5.35 |
| 5 | | | | | | | 5.0 | | | 3.55 | 4.8 | 5.35 |
| 6 | 5.7 | 6.9 | 5.8 | 5.0 | | | 5.0 | | | 3.5 | 4.8 | 5.4 |
| 7 | 5.65 | 6.8 | | | | | 5.0 | | | 3.5 | 4.8 | 5.4 |
| 8 | 5.65 | 6.85 | 5.75 | | | | 5.5 | | | 3.6 | 4.85 | 5.35 |
| 9 | | 6.8 | 5.45 | | | | 5.1 | | | 3.8 | 4.85 | 5.4 |
| 10 | | 6.85 | 5.4 | | | | 5.1 | | | 3.85 | 4.9 | 5.4 |
| 11 | | 6.9 | 5.45 | | | | 5.2 | | | 3.9 | 4.9 | 5.4 |
| 12 | | 6.9 | 5.4 | | | | 5.25 | | | 3.9 | 4.9 | 5.35 |
| 13 | | | 5.7 | | | | 5.3 | | | 4.0 | 4.9 | 5.4 |
| 14 | 5.7 | 7.1 | | 4.5 | | | 5.3 | | | 4.1 | 4.95 | 5.4 |
| 15 | 5.8 | 7.15 | 5.8 | | | | 5.3 | | | 4.15 | 4.95 | 5.4 |
| 16 | | 7.2 | 6.3 | | | | 5.3 | | | 4.15 | 5.0 | 5.4 |
| 17 | | 7.2 | 6.4 | | | | 5.0 | | 3.1 | 4.2 | 5.0 | 5.5 |
| 18 | | | | | | | 4.8 | | 3.1 | 4.25 | 5.0 | 5.45 |
| 19 | 5.8 | | | | | | 4.75 | | 3.2 | 4.3 | 5.0 | 5.4 |
| 20 | 5.9 | | | | | | 4.6 | | 3.3 | 4.3 | 5.0 | 5.5 |
| 21 | 5.85 | 5.8 | | | | | 4.4 | | 3.3 | 4.4 | 5.0 | 5.4 |
| 22 | | 5.8 | | | | | 4.1 | | 3.3 | 4.4 | 5.0 | 5.45 |
| 23 | 6.0 | 5.8 | | | | 6.0 | 3.5 | | 3.3 | 4.5 | 5.0 | 5.5 |
| 24 | | | | | | 6.1 | 3.2 | | 3.2 | 4.5 | 5.0 | 5.5 |
| 25 | | | | | | 6.3 | 3.0 | | 3.25 | 4.4 | 5.0 | 5.45 |
| 26 | 6.0 | 5.8 | | | | 6.4 | 2.8 | | 3.3 | 4.45 | 5.0 | 5.45 |
| 27 | 6.0 | | | | | 6.35 | 2.75 | | 3.35 | 4.5 | 5.0 | 5.4 |
| 28 | | | | | | 6.0 | 2.6 | | 3.4 | 4.5 | 5.0 | 5.5 |
| 29 | | | | | | 5.6 | 2.5 | | 3.4 | 4.5 | 5.0 | 5.4 |
| 30 | 5.8 | | | | | 5.6 | | | 3.45 | 4.55 | 5.0 | 5.45 |
| 31 | | | | | | | | | | 4.6 | | 5.45 |

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*Station rating table for Owens River near Citrus, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.50 | 0 | 3.70 | 63 | 4.90 | 217 | 6.10 | 440 |
| 2.60 | 1 | 3.80 | 73 | 5.00 | 233 | 6.20 | 462 |
| 2.70 | 3 | 3.90 | 83 | 5.10 | 249 | 6.30 | 485 |
| 2.80 | 5 | 4.00 | 94 | 5.20 | 266 | 6.40 | 508 |
| 2.90 | 8 | 4.10 | 105 | 5.30 | 283 | 6.50 | 532 |
| 3.00 | 12 | 4.20 | 117 | 5.40 | 301 | 6.60 | 556 |
| 3.10 | 18 | 4.30 | 130 | 5.50 | 319 | 6.70 | 581 |
| 3.20 | 24 | 4.40 | 144 | 5.60 | 337 | 6.80 | 607 |
| 3.30 | 31 | 4.50 | 158 | 5.70 | 356 | 6.90 | 634 |
| 3.40 | 38 | 4.60 | 172 | 5.80 | 376 | 7.00 | 662 |
| 3.50 | 46 | 4.70 | 187 | 5.90 | 397 | 7.10 | 690 |
| 3.60 | 54 | 4.80 | 202 | 6.00 | 418 | 7.20 | 720 |

NOTE.—The above table is based on 11 discharge measurements made during 1904–5. It is fairly well defined between gage heights 3 feet and 7 feet.

*Estimated monthly discharge of Owens River near Citrus, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January [a] | 418 | 283 | 369 | 22,690 |
| February [a] | 720 | 376 | 540 | 29,990 |
| March 1–17 [a] | 508 | 301 | 372 | 12,540 |
| June 23–30 | 508 | 337 | 430 | 6,823 |
| July | 337 | 0 | 175 | 10,760 |
| September 17–30 | 42 | 18 | 29.9 | 830 |
| October | 172 | 42 | 107 | 6,579 |
| November | 233 | 172 | 219 | 13,030 |
| December | 319 | 292 | 301 | 18,510 |
| The period | | | | 121,800 |

[a] Missing gage heights interpolated.

### POWERS CANAL NEAR BISHOP, CAL.

This station was established August 19, 1903, by R. S. Hawley. It is located one-half mile above a mill on Bishop Creek, and 4½ miles west of Bishop, Cal.

The canal is straight for 20 feet above and 50 feet below the station. The bed of the canal is composed of gravel and is not subject to change.

Discharge measurements are made by wading.

The gage is a rod on the left bank of the canal. The bench mark is on granite bowlder 60 feet north of penstock of the mill pressure pipe; elevation, 3.50 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 134, pp 251-252.
Discharge: 134, p 252.
Discharge, monthly: 134, p 253.
Gage heights: 134, p 252.
Rating table: 134, p 252.

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*Discharge measurements of Powers canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| April 3 | J. S. Evans | 3 | 0.7 | 1.00 | 1.10 | 0.7 |
| June 21 | do | 9 | 6.4 | 2.66 | 1.90 | 17.0 |
| July 27 | do | 8 | 5.0 | 2.36 | 1.68 | 11.8 |
| August 10 | do | 7 | 1.3 | 1.08 | 1.30 | 1.4 |
| September 7 | do | 7.5 | 2.1 | 1.33 | 1.40 | 2.8 |
| November 23 | F. R. S. Buttemer | 8 | 1.4 | .79 | 1.25 | 1.1 |
| December 11 | do | 8 | 3.6 | .89 | 1.58 | 3.2 |
| December 21 | do | | | | 1.16 | 1.0 |

### SOUTH HILLSIDE CANAL NEAR BISHOP, CAL.

This station was established August 26, 1903, by R. S. Hawley. It is located just below waste gate at head of canal, 5 miles west of Bishop, Cal.

Discharge measurements are made by wading.

The gage is a rod on the left bank of the canal. The bench mark is on granite bowlder marked by ring of white paint and located on left bank 2 feet from gage; elevation, 2.99 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 134, p 253.
Discharge: 134, p 253.
Discharge, monthly: 134, p 255.
Gage heights: 134, p 254.
Rating table: 134, p 254.

*Discharge measurements of South Hillside canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 21 | R. J. Taylor | 4.5 | 0.9 | 1.11 | 1.60 | 1.0 |
| February 8 | do | 4.5 | .9 | 1.11 | 1.60 | 1.0 |
| March 4 | do | 4.5 | 1.3 | 1.46 | 1.66 | 1.9 |
| April 18 | J. S. Evans | 4.8 | 1.6 | 1.88 | 1.70 | 3.0 |
| May 5 | do | 4.8 | 3.2 | 2.66 | 2.00 | 8.5 |
| July 27 | do | 4.5 | 2.4 | 3.29 | 1.98 | 7.9 |
| August 10 | do | 5.0 | 3.6 | 2.47 | 2.00 | 8.9 |
| September 22 | do | 4.5 | 3.2 | 2.75 | 2.00 | 8.8 |
| October 25 | F. R. S. Buttemer | 4.0 | 2.0 | 1.75 | 1.75 | 3.5 |
| November 23 | do | 5.0 | 1.0 | .90 | 1.58 | .9 |
| December 11 | do | 3.7 | .6 | .50 | 1.50 | .3 |

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### NORTH HILLSIDE CANAL NEAR BISHOP, CAL.

This station was established September 3, 1903, by R. S. Hawley. It is located at head gate of the canal, 5 miles west of Bishop, Cal.

Discharge measurements are made from crosspiece of the flume on which the distances across are marked at each foot. The initial point for soundings is the end of crosspiece of flume at right bank.

The gage is a vertical rod fastened to the right side of flume or head gate. The bench mark is on a granite bowlder marked with white paint and located near gage; elevation, 2.96 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 134, p 255.
Discharge: 134, p 255.
Discharge, monthly: 134, p 256.
Gage heights: 134, p 256.
Rating table: 134, p 256.

*Discharge measurements of North Hillside Canal near Bishop, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 4 | R. J. Taylor | 4.3 | 1.8 | 0.83 | 1.51 | 1.5 |
| April 18 | J. S. Evans | 4 | 2.2 | 2.23 | 1.70 | 4.9 |
| May 5 | do | 4 | 3.6 | 3.33 | 2.00 | 12.0 |
| June 21 | do | 4 | 3.0 | 7.67 | 2.10 | 23.0 |
| July 27 | do | 4 | 2.4 | 7.83 | 2.05 | 18.8 |
| August 10 | do | 4 | 2.6 | 7.46 | 2.08 | 19.4 |
| September 17 | do | 4 | 3.2 | 3.70 | 1.98 | 11.8 |
| September 22 | do | 4.2 | 2.5 | 5.20 | 2.0 | 13.0 |
| October 23 | do | 4.0 | 2.0 | 1.95 | 1.70 | 3.9 |
| November 23 | do | 6 | 2.4 | 1.21 | 1.70 | 2.9 |
| December 11 | do | 4.3 | 2.2 | .32 | 1.52 | .7 |
| December 21 | F. R. S. Buttemer | 4.5 | .8 | .75 | 1.45 | .6 |

### BIG PINE CREEK NEAR BIG PINE, CAL.

This station was established December 5, 1903, by R. S. Hawley. It is located 3 miles southwest of Big Pine, Cal., at a point where the creek leaves the foothills.

The channel is straight for 30 feet above and 50 feet below the station. The current is swift at all stages. Both banks are high and rocky. The bed of the stream is rough and rocky, and is not subject to much change.

Discharge measurements are made from a footbridge. The initial point is at the right bank.

The gage is a veritical rod fastened to a tree on the left bank of the creek, 3 feet above the footbridge. During 1905 the gage was read by Mrs. J. M. Randle. Bench marks were established as follows: (1) On a granite bowlder marked by a ring of white paint, 40 feet southeast of the south end of the footbridge; elevation, 8.54 feet; (2) a point marked with a ring of white paint, 45 feet southwest of the south end of the footbridge; elevation, 10.44 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 134, p 257.
Discharge: 134, pp 257, 260.
Discharge, monthly: 134, p 259.
Gage heights: 134, p 258.
Rating table: 134, p 258.

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*Discharge measurements of Big Pine Creek near Big Pine, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 18 | R. J. Taylor | 13 | 9.9 | 2.52 | 1.95 | 25 |
| February 18 | do | 12.5 | 8.5 | 2.71 | 1.85 | 23 |
| April 26 | J. S. Evans | 13 | 10.8 | 2.78 | 2.20 | 30 |
| May 19 | do | 13 | 13.8 | 3.70 | 2.38 | 51 |
| June 9 | do | 13 | 15.8 | 3.86 | 2.48 | 61 |
| July 16 | do | 13.5 | 21.0 | 5.71 | 2.85 | 120 |
| August 17 | do | 13 | 18.4 | 4.77 | 2.60 | 88 |
| September 13 | do | 13 | 13.0 | 3.15 | 2.30 | 41 |
| November 16 | F. R. S. Buttermer | 10 | 6.6 | 1.61 | 1.85 | 10.6 |
| December 1 | do | 13.5 | 8.8 | 1.62 | 2.00 | 14.3 |
| December 16 | do | 13.5 | 12.6 | 0.83 | 2.20 | 10.5 |
| December 16 | do | 13.5 | 12.5 | 0.98 | 2.20 | 12.2 |

[a] Channel changed.

*Daily gage height, in feet, of Big Pine Creek near Big Pine, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.85 | 1.9 | 1.85 | 1.8 | 2.5 | 2.4 | 2.95 | 2.9 | 2.7 | 2 25 | 1.8 | ..... |
| 2 | 1.85 | 1.9 | 1.9 | 1.9 | 2.5 | 2.4 | 3.0 | 2.9 | 2.6 | 2.15 | ..... | 1.9 |
| 3 | 1.85 | 1.9 | 1.9 | 1.85 | 2.5 | 2.4 | 3.0 | 2.9 | 2.5 | 2.15 | ..... | ..... |
| 4 | 1.85 | 2.0 | 1.9 | 1.9 | 2.5 | 2.4 | 3.0 | 2.9 | 2.4 | 2.15 | ..... | 1.9 |
| 5 | 1.85 | 2 0 | 1.9 | 1.9 | 2.4 | 2.4 | 3.0 | 2.9 | 2.4 | 2.1 | ..... | ..... |
| 6 | 1.85 | 2.0 | 1.9 | 1.85 | 2.4 | 2.45 | 3.0 | 2.9 | 2.35 | 2.0 | ..... | ..... |
| 7 | 1.85 | 1.95 | 1.9 | 1.85 | 2.4 | 2.45 | 3.0 | 2.8 | 2.25 | 2.0 | ..... | ..... |
| 8 | 1.85 | 1.95 | 1.9 | 1.9 | 2.3 | 2.5 | 3.0 | 2.8 | 2.25 | 2.0 | 1.8 | ..... |
| 9 | 1.9 | 1.9 | 1.9 | 1.95 | 2.0 | 2.5 | 3.2 | 2.9 | 2.2 | 2.0 | ..... | 1.9 |
| 10 | 1.9 | 1.9 | 1.85 | 1.95 | 2.0 | 2.5 | 3.5 | 3.0 | 2.3 | 2.0 | ..... | ..... |
| 11 | 1.85 | 1.9 | 1.85 | 1.95 | 2 0 | 2.7 | 3.5 | 3.0 | 2.4 | 2.0 | 1.85 | 2.0 |
| 12 | 1.8 | 1.9 | 1.9 | 1.95 | 2.0 | 2.8 | 3.5 | 3.0 | 2.4 | 2.0 | ..... | ..... |
| 13 | 1.8 | 1.9 | 1.9 | 1.95 | 2.1 | 2.9 | 3.3 | 2.9 | 2.45 | 2.0 | ..... | ..... |
| 14 | 1.8 | 1.9 | 1.9 | 1.95 | 2.2 | 2.9 | 3.3 | 2.9 | 2.45 | 2.0 | ..... | ..... |
| 15 | 1.8 | 1.85 | 1.9 | 1.95 | 2.3 | 2.9 | 3.3 | 2.9 | 2.45 | 1.85 | 1.85 | 2.0 |
| 16 | 1.85 | 1.85 | 1.9 | 1.95 | 2.3 | 2.9 | 3.05 | 2.9 | 2.45 | 1.85 | ..... | ..... |
| 17 | 1.85 | 1.85 | 1.9 | 1.95 | 2.3 | 2.95 | 3.2 | 2.9 | 2.35 | 1.8 | ..... | ..... |
| 18 | 1.85 | 1.85 | 1.9 | 1 95 | 2.4 | 3.0 | 3.1 | 2.8 | 2.4 | 1.8 | 1.8 | ..... |
| 19 | 1.85 | 1.85 | 1.9 | 1.95 | 2.4 | 3.0 | 3.0 | 2.8 | 2.45 | 1.8 | ..... | ..... |
| 20 | 1.85 | 1.85 | 1.9 | 1.95 | 2.4 | 3.0 | 3.0 | 2.9 | 2.45 | 1.8 | ..... | 2.2 |
| 21 | 1.85 | 1.85 | 1.9 | 1.95 | 2.5 | 3.2 | 3.0 | 2.8 | 2.4 | 1.8 | ..... | ..... |
| 22 | 1.8 | 1.85 | 1.9 | 1.95 | 2.5 | 3.3 | 3.0 | 2.8 | 2.4 | 1.8 | ..... | ..... |
| 23 | 1.85 | 1.85 | 1.9 | 2.0 | 2.4 | 3.4 | 3.1 | 2.7 | 2.4 | 1.8 | 1.85 | 2.15 |
| 24 | 1.85 | 1.85 | 1.9 | 2.0 | 2.4 | 3.2 | 3.2 | 2.7 | 2.35 | 1.8 | ..... | ..... |
| 25 | 1.85 | 1.85 | 1.9 | 2.0 | 2.4 | 2.8 | 3.3 | 2.7 | 2.3 | 1.8 | ..... | ..... |
| 26 | 1.85 | 1.85 | 1.9 | 2.2 | 2.4 | 2.8 | 3.4 | 2.7 | 2.3 | 1.8 | ..... | 2.3 |
| 27 | 1.85 | 1.85 | 1.9 | 2.3 | 2.4 | 2.8 | 3.3 | 2.7 | 2.3 | 1.8 | ..... | ..... |
| 28 | 1.85 | 1.85 | 1.8 | 2.3 | 2.4 | 2.9 | 3.2 | 2.7 | 2.3 | 1.8 | 1.85 | ..... |
| 29 | 1.85 | ..... | 1.8 | 2.4 | 2.4 | 2.9 | 3.1 | 2.7 | 2.3 | 1.8 | ..... | ..... |
| 30 | 1.85 | ..... | 1.8 | 2.5 | 2.4 | 2.9 | 3.1 | 2.7 | 2.3 | 1.8 | ..... | ..... |
| 31 | 1.85 | ..... | 1.8 | ..... | 2.4 | ..... | 3.0 | 2.7 | ..... | 1.8 | ..... | ..... |

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*Station rating table for Big Pine Creek near Big Pine, Cal., from March 21 to December 15, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.80 | 9 | 2.30 | 40 | 2.80 | 115 | 3.30 | 220 |
| 1.90 | 11 | 2.40 | 52 | 2.90 | 134 | 3.40 | 244 |
| 2.00 | 15 | 2.50 | 66 | 3.00 | 154 | 3.50 | 268 |
| 2.10 | 21 | 2.60 | 81 | 3.10 | 175 | | |
| 2.20 | 30 | 2.70 | 97 | 3.20 | 197 | | |

NOTE.—The above table is based on eight discharge measurements made during 1905. It is fairly well defined between gage heights 2 feet and 2.8 feet. The table has been extended beyond these limits, being based on extension of area and mean-velocity curves.

*Estimated monthly discharge of Big Pine Creek near Big Pine, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 24 | 19 | 21.7 | 1,334 |
| February | 30 | 22 | 23.9 | 1,327 |
| March | 24 | 9 | 18.9 | 1,162 |
| April | 66 | 9 | 17.9 | 1,065 |
| May | 66 | 15 | 46.7 | 2,872 |
| June | 244 | 52 | 118 | 7,021 |
| July | 268 | 144 | 187 | 11,500 |
| August | 154 | 97 | 122 | 7,501 |
| September | 97 | 30 | 51.1 | 3,041 |
| October | 35 | 9 | 13.7 | 842 |
| November | 10 | 9 | 9.6 | 571 |
| December 1-15 | 15 | 11 | 12.5 | 372 |
| The period | | | | 38,610 |

NOTE.—Discharge January 1 to March 20 based on discharge measurements directly. Rating table used March 21 to December 15. Because of a change in channel the rating table does not apply after December 15.

Discharges for days in November and December, when gage heights are not recorded, were interpolated.

### BIRCH CREEK NEAR TINEMAHA, CAL.

This station was established June 14, 1905, by J. S. Evans. It is located 6 miles southwest of Big Pine and 500 feet west of ranch of Charles Peterson.

The channel is straight for 25 feet above and below the station. The water is swift at all stages. Both banks are low, but not subject to overflow. The bed of the stream is composed of coarse gravel and is not subject to material change. The stream flows in one channel.

Discharge measurements are made from a footbridge, which consists of a cottonwood tree placed across the stream. The initial point for soundings is a nail in footbridge on the left bank.

The gage is a vertical staff nailed to a willow tree on the left bank. During 1905 the gage was read by Charles Peterson. The bench mark is a nail in the top of a willow stump on the left bank; elevation, 2.00 feet above the datum of the gage.

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*Discharge measurements of Birch Creek near Tinemaha, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| June 14 | J. S. Evans | 7 | 9.6 | 2.19 | 1.00 | 21 |
| July 17 | do | 8 | 8.0 | 1.35 | .71 | 10.8 |
| August 24 | do | 8 | 7.6 | 1.00 | .58 | 7.6 |
| November 17 | F. R. S. Buttemer | 8 | 6.2 | .35 | .55 | 2.2 |
| December 2 | do | 8 | 6.0 | .42 | .55 | 2.5 |

*Daily gage height, in feet, of Birch Creek near Tinemaha, Cal., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|
| 1 | ..... | 0.8 | 0.65 | 0.6 | 0.5 | 0.35 | 0.8 |
| 2 | ..... | .75 | .65 | .55 | .4 | .35 | .55 |
| 3 | ..... | .75 | .65 | .6 | .4 | .35 | .55 |
| 4 | ..... | .8 | .65 | .55 | .35 | .45 | .55 |
| 5 | ..... | .8 | .6 | .55 | .35 | .5 | .5 |
| 6 | ..... | .8 | .55 | .5 | .3 | .5 | .5 |
| 7 | ..... | .85 | .6 | .5 | .3 | .5 | .5 |
| 8 | ..... | .9 | .65 | .45 | .3 | .5 | .5 |
| 9 | ..... | .9 | .75 | .45 | .35 | .5 | .5 |
| 10 | ..... | .85 | .8 | .5 | .35 | .5 | ..... |
| 11 | ..... | .9 | .65 | .5 | .35 | .5 | ..... |
| 12 | ..... | .9 | .6 | .5 | .35 | .5 | ..... |
| 13 | ..... | .85 | .6 | .45 | .35 | .5 | ..... |
| 14 | 1.0 | .75 | .6 | .45 | .35 | .5 | ..... |
| 15 | ..... | .7 | .6 | .45 | .35 | .5 | ..... |
| 16 | ..... | .7 | .55 | .4 | .35 | .5 | ..... |
| 17 | ..... | .7 | .55 | .4 | .35 | .5 | ..... |
| 18 | .9 | .7 | .55 | .4 | .35 | .5 | ..... |
| 19 | .9 | .65 | .5 | .4 | .35 | .5 | ..... |
| 20 | .9 | .65 | .6 | .4 | .35 | .5 | ..... |
| 21 | .8 | .65 | .65 | .4 | .35 | .5 | ..... |
| 22 | 1.0 | .65 | .65 | .4 | .35 | .5 | ..... |
| 23 | .8 | .7 | .55 | .4 | .35 | .5 | ..... |
| 24 | .9 | .7 | .55 | .4 | .35 | .5 | ..... |
| 25 | .75 | .75 | .55 | .4 | .35 | .5 | ..... |
| 26 | .75 | .8 | .55 | .4 | .35 | .5 | ..... |
| 27 | .75 | .8 | .6 | .4 | .35 | .5 | ..... |
| 28 | .75 | .75 | .6 | .4 | .35 | .65 | ..... |
| 29 | .8 | .7 | .65 | .45 | .35 | .7 | ..... |
| 30 | .85 | .65 | .65 | .45 | .35 | .6 | ..... |
| 31 | ..... | .65 | .65 | ..... | .35 | ..... | ..... |

### INDEPENDENCE CREEK NEAR INDEPENDENCE, CAL.

This station was established June 15, 1905, by J. S. Evans. It is located about 1 mile west of the town of Independence near intake of the city waterworks of Independence.

The channel is straight for 25 feet above and below the gaging station. Both banks are low, but not subject to overflow. The bed of the stream is composed of gravel and rocks. The approximate depth of water is 1.2 feet. The stream discharges in one channel.

Discharge measurements are made by wading. The initial point for soundings is on the right bank.

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The gage is a vertical timber nailed to a willow tree on the right bank. During 1905 the gage was read by Milton Levy. The bench mark is a cross on large rock on right bank of the stream; elevation, 1.70 feet above the datum of the gage.

*Discharge measurements of Independence Creek near Independence, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| June 15 | J. S. Evans | 12 | 13.6 | 3.46 | 1.10 | 47 |
| July 21 | do | 12 | 8.0 | 2.42 | .72 | 19.4 |
| August 23 | do | 11 | 5.0 | 1.46 | .47 | 7.3 |
| November 11 | F. R. S. Buttemer | 11 | 3.9 | .79 | .35 | 3.1 |
| December 3 | do | 11 | 4.6 | .80 | .37 | 3.7 |

*Daily gage height, in feet, of Independence Creek near Independence, Cal., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|
| 1 | | 0.9 | 0.65 | 0.45 | 0.35 | 0.35 | 0.4 |
| 2 | | .9 | .65 | .45 | .35 | .35 | .4 |
| 3 | | .85 | .65 | .45 | .35 | .35 | .4 |
| 4 | | .85 | .6 | .45 | .35 | .35 | .4 |
| 5 | | .85 | .6 | .45 | .35 | .35 | .4 |
| 6 | | .85 | .6 | .45 | .35 | .35 | .4 |
| 7 | | .9 | .55 | .45 | .35 | .35 | .4 |
| 8 | | .85 | .55 | .45 | .35 | .35 | .35 |
| 9 | | .85 | .55 | .45 | .3 | .35 | .4 |
| 10 | | .85 | .55 | .35 | .35 | .35 | .4 |
| 11 | | .9 | .55 | .35 | .35 | .35 | .4 |
| 12 | | .9 | .55 | .35 | .35 | .35 | .3 |
| 13 | | .9 | .55 | .4 | .35 | .35 | .35 |
| 14 | | .85 | .55 | .4 | .35 | .35 | .35 |
| 15 | 1.1 | .8 | .55 | .35 | .4 | .35 | .4 |
| 16 | 1.1 | .8 | .55 | .35 | .4 | .35 | .4 |
| 17 | 1.1 | .75 | .55 | .4 | .35 | .35 | .4 |
| 18 | 1.1 | .75 | .55 | .4 | .35 | .35 | .35 |
| 19 | 1.1 | .75 | .55 | .4 | .35 | .35 | .4 |
| 20 | 1.1 | .75 | .55 | .35 | .35 | .35 | .4 |
| 21 | 1.1 | .7 | .55 | .35 | .4 | .35 | .3 |
| 22 | 1.05 | .7 | .55 | .35 | .35 | .35 | .3 |
| 23 | 1.05 | .7 | .55 | .4 | .35 | .4 | .35 |
| 24 | 1.1 | .7 | .55 | .4 | .35 | .4 | .35 |
| 25 | .95 | .7 | .55 | .35 | .35 | .4 | .3 |
| 26 | .95 | .7 | .55 | .35 | .35 | .4 | .3 |
| 27 | .95 | .7 | .5 | .35 | .35 | .4 | .3 |
| 28 | .95 | .7 | .5 | .35 | .35 | .4 | .35 |
| 29 | .9 | .7 | .5 | .35 | .35 | .4 | .35 |
| 30 | .9 | .7 | .5 | .35 | .35 | .4 | .35 |
| 31 | | .65 | .45 | | .35 | | .35 |

NOTE.—Gage heights interpolated June 16–20; October 29 to November 10; November 12 to December 2.

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*Station rating table for Independence Creek near Independence, Cal., from June 15 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.30 | 1.6 | 0.60 | 12.9 | 0.80 | 24 | 1.00 | 39 |
| 0.40 | 4.8 | 0.70 | 18 | 0.90 | 31 | 1.10 | 47 |
| 0.50 | 8.5 | | | | | | |

NOTE.—The above table is based on five discharge measurements made during 1905. It is well defind between gage heights 0.4 foot and 1.1 feet.

*Estimated monthly discharge of Independence Creek near Independence, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| June 15-30 | 47 | 31 | 41.5 | 1,317 |
| July | 31 | 15.4 | 23.5 | 1,445 |
| August | 15.4 | 6.6 | 10.9 | 670 |
| September | 6.6 | 3.1 | 4.6 | 274 |
| October | 4.8 | 1.6 | 3.2 | 198 |
| November | 4.8 | 3.1 | 3.6 | 214 |
| December | 4.8 | 1.6 | 3.6 | 223 |
| The period | | | | 4,341 |

### OAK CREEK NEAR INDEPENDENCE, CAL.

This station was established June 15, 1905, by J. S. Evans. It is located about 1 mile west of old Fort Independence and 3 miles northwest of the town of Independence.

The channel is straight for a short distance above and below the station. Both banks are low and subject to slight overflow in high water. The bed of the stream is composed of gravel and rocks, with high velocity at all stages. The stream flows in one channel and has an average depth of 1.2 feet.

Discharge measurements are usually made by wading, although a plank placed across the stream is used as a footbridge for higher stages of the water. The initial point for soundings is a nail in the footbridge on the left bank.

The gage is a staff nailed to a stake driven on the left bank of the stream. During 1905 the gage was read by A. M. Bell. The bench mark is a nail driven in the top of a stake set firmly in the ground on the right bank of the stream near the end of the footbridge; elevation, 1.30 feet above the datum of the gage.

*Discharge measurements of Oak Creek near Independence, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| June 15 | J. S. Evans | 6 | 8.4 | 3.81 | 1.10 | 32 |
| July 17 | do | 5 | 4.4 | 4.00 | .63 | 17.6 |
| August 23 | do | 5 | 2.8 | 4.18 | .30 | 11.7 |
| November 8 | F. R. S. Buttemer | 5 | 3.4 | 3.24 | .35 | 11.0 |
| December 4 | do | 6 | 3.1 | 1.87 | .25 | 5.8 |

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*Daily gage height, in feet, of Oak Creek near Independence, Cal., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.0 | 0.6 | 0.4 | 0.3 | 0.3 | 0.3 |
| 2 | ..... | 1.0 | .5 | .4 | .3 | .3 | .3 |
| 3 | ..... | 1.0 | .5 | .4 | .3 | .3 | .25 |
| 4 | ..... | .9 | .5 | .4 | .3 | .3 | .25 |
| 5 | ..... | 1.0 | .5 | .4 | .2 | .3 | .3 |
| 6 | ..... | 1.0 | .5 | .3 | .2 | .4 | .3 |
| 7 | ..... | 1.0 | .5 | .3 | .2 | .4 | .25 |
| 8 | ..... | 1.0 | .5 | .3 | .3 | .3 | .25 |
| 9 | ..... | 1.0 | .5 | .3 | .3 | .4 | .25 |
| 10 | ..... | 1.1 | .5 | .3 | .3 | .3 | .25 |
| 11 | ..... | 1.1 | .5 | .3 | .3 | .3 | .25 |
| 12 | ..... | 1.1 | .5 | .3 | .3 | .3 | .25 |
| 13 | ..... | 1.0 | .5 | .3 | .3 | .3 | .3 |
| 14 | ..... | .9 | .4 | .3 | .2 | .3 | .3 |
| 15 | ..... | .9 | .4 | .3 | .3 | .3 | .3 |
| 16 | ..... | .8 | .4 | .2 | .2 | .3 | .3 |
| 17 | ..... | .8 | .4 | .2 | .2 | .3 | .25 |
| 18 | 1.3 | .7 | .4 | .2 | .3 | .3 | .25 |
| 19 | 1.3 | .7 | .4 | .2 | .3 | .3 | .25 |
| 20 | 1.3 | .6 | .4 | .2 | .3 | .3 | .25 |
| 21 | 1.4 | .7 | .4 | .2 | .3 | .3 | .25 |
| 22 | 1.2 | .6 | .4 | .2 | .3 | .3 | .25 |
| 23 | 1.2 | .6 | .4 | .2 | .3 | .3 | .25 |
| 24 | 1.1 | .7 | .4 | .2 | .3 | .3 | .25 |
| 25 | 1.0 | .7 | .4 | .2 | .3 | .3 | .25 |
| 26 | 1.0 | .7 | .4 | .2 | .3 | .3 | .25 |
| 27 | 1.0 | .7 | .4 | .2 | .3 | .3 | .25 |
| 28 | .9 | .7 | .4 | .2 | .3 | .3 | .25 |
| 29 | 1.0 | .6 | .4 | .2 | .3 | .3 | .25 |
| 30 | 1.0 | .6 | .4 | .3 | .3 | .3 | .25 |
| 31 | ..... | .6 | .4 | ..... | .3 | ..... | .25 |

## MISCELLANEOUS MEASUREMENTS IN OWENS RIVER DRAINAGE BASIN.

The following is a list of the miscellaneous discharge measurements made in the Owens River drainage basin during 1905:

*Ash Creek near Lone Pine, Cal.*—This stream discharges into Owens Lake from the eastern slope of the Sierra Nevada. The following measurements were made during 1905 at a point where the stream leaves the foothills and enters the valley:

June 19: Width, 10 feet; area, 5.4 square feet; mean velocity, 1.96 feet per second; discharge, 10.6 second-feet.

July 19: Width, 4 feet; area, 1 square foot; mean velocity, 1.80 feet per second; discharge, 1.8 second-feet.

*Birch Creek near Bishop, Cal.*—This stream is tributary to Owens River above Bishop, Cal. A measurement was made August 1, 1905, by J. S. Evans at the point where the stream leaves the foothills and enters the valley.

Width, 6 feet; area, 4.4 square feet; mean velocity, 2.72 feet per second; discharge, 12 second-feet.

*Clear Creek near Big Pine, Cal.*—This stream is tributary to Owens River from the eastern slope of the Sierra Nevada. The following measurements were made during 1905 at a point where the stream leaves the foothills and enters the valley:

June 14: Width, 7 feet; area, 5.6 square feet; mean velocity, 1.86 feet per second; discharge, 10.4 second-feet.

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July 17: Width, 6 feet; area, 3.4 square feet; mean velocity, 1.61 feet per second; discharge, 5.5 second-feet.

*Cottonwood Creek near Olancha, Cal.*—This stream discharges into Owens Lake from the eastern slope of the Sierra Nevada. The gage rod is a 1 by 3 inch timber graduated to feet and tenths and nailed to a cottonwood tree on the right bank of the stream. The following measurements were made during 1905 at a point where the stream leaves the foothills and enters the valley:

June 16: Width, 28 feet; area, 30 square feet; mean velocity, 3.03 feet per second; gage height, 0.80 foot; discharge, 91 second-feet.

July 20: Width, 20 feet; area, 16.2 square feet; mean velocity, 1.86 feet per second; gage height, 0.33 foot; discharge, 30 second-feet.

November 10: Width, 8 feet; area, 5 square feet; mean velocity, 0.86 foot per second; discharge, 4.3 second-feet.

*Division Creek near Independence, Cal.*—This stream is tributary to Owens River from the eastern slope of the Sierra Nevada. The following discharge measurements were made during 1905 at a point where the stream leaves the foothills and enters the valley:

June 14: Width, 4 feet; area, 1.9 square feet; mean velocity, 1.74 feet per second; discharge, 3.3 second-feet.

July 17: Width, 4 feet; area, 1.2 square feet; mean velocity, 1.75 feet per second; discharge, 2.1 second-feet.

December 2: Width, 6.5 feet; area, 2.9 square feet; mean velocity, 1.86 feet per second; discharge, 5.4 second-feet.

*Eight Mile Creek near Independence, Cal.*—This stream is tributary to Owens River from the eastern slope of the Sierra Nevada. A measurement was made December 4, 1905, at a point where the stream leaves the foothills and enters the valley:

Width, 4.5 feet; area, 2.2 square feet; mean velocity, 1.45 feet per second; discharge, 3.2 second-feet.

*Fish Springs near Big Pine, Cal.*—A measurement was made of the water discharging from these springs on December 4, 1905:

Width, 7 feet; area, 20 square feet; mean velocity, 1.45 feet per second; discharge, 29 second-feet.

*Goodale Creek near Tibbetts, Cal.*—This stream is a tributary to Owens River from the eastern slope of the Sierra Nevada. The following measurements were made during 1905 at a point where the stream leaves the foothills and enters the valley:

June 14: Width, 4.5 feet; area, 2.6 square feet; mean velocity, 2.27 feet per second; discharge, 5.9 second-feet.

July 17: Width, 3.5 feet; area, 1.8 square feet; mean velocity, 1.94 feet per second; discharge, 3.5 second-feet.

August 22: Width, 3 feet; area, 1.5 square feet; mean velocity, 2.26 feet per second; discharge, 3.4 second-feet.

November 17: Width, 3.7 feet; area, 2.2 square feet; mean velocity, 2.09 feet per second; discharge, 4.6 second-feet.

*Georges Creek near Independence, Cal.*—This stream is tributary to Owens River from the eastern slope of the Sierra Nevada. A measurement was made June 15, 1905, at a point where the stream leaves the foothills and enters the valley:

Width, 11 feet; area, 9.2 square feet; mean velocity, 2.61 feet per second; discharge, 24 second-feet.

*Lone Pine Creek near Lone Pine, Cal.*—This stream is tributary to Owens River from the eastern slope of the Sierra Nevada. The following measurements were made during 1905 at a point where the stream leaves the foothills and enters the valley:

June 15: Width, 13 feet; area, 14.2 square feet; mean velocity, 2.61 feet per second; discharge, 37 second-feet.

July 19: Width, 13 feet; area, 13 square feet; mean velocity, 2.31 feet per second; discharge, 30 second-feet.

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November 9: Width, 12.5 feet; area, 4.2 square feet; mean velocity, 0.83 foot per second; discharge, 3.5 second-feet.

*Moffett Creek near Independence, Cal.*—This stream is tributary to Owens River from the eastern slope of the Sierra Nevada. A measurement was made on June 15 at a point where the stream leaves the foothills and enters the valley:

Width, 7 feet; area, 4 square feet; mean velocity, 2.25 feet per second; discharge, 9 second-feet.

*McGee Creek near Bishop, Cal.*—This stream is tributary to Owens River from the eastern slope of the Sierra Nevada. A measurement was made on August 1, 1905, at a point where the stream leaves the foothills and enters the valley:

Width, 4 feet; area, 4 square feet; mean velocity, 2.18 feet per second; discharge, 8.7 second-feet.

*Shepherds Creek near Independence, Cal.*—This stream is tributary to Owens River from the eastern slope of the Sierra Nevada. The following measurements were made during 1905 at a point where the stream leaves the foothills and enters the valley:

June 15: Width, 6 feet; area, 6 square feet; mean velocity, 2.53 feet per second; discharge, 15.2 second-feet.

July 18: Width, 6 feet; area, 2.7 square feet; mean velocity, 2.37 feet per second; discharge, 6.4 second-feet.

*Taboose Creek near Tibbetts, Cal.*—This stream is tributary to Owens River from the eastern slope of the Sierra Nevada. The gage rod is a 1 by 3 inch timber graduated to feet and tenths and nailed to a willow tree on the left bank of the stream. The bench mark is a nail in willow tree on the left bank, to which gage is fastened. Its elevation is 1.60 feet above the zero of the gage. The following measurements were made during 1905 at a point where the stream leaves the foothills and enters the valley:

June 14: Width, 10 feet; area, 10.6 square feet; mean velocity, 1.68 feet per second; gage height, 0.60 foot; discharge, 17.8 second-feet.

July 17: Width, 10 feet; area, 6.6 square feet; mean velocity, 1.82 feet per second; gage height, 0.40 foot; discharge, 12 second-feet.

August 24: Width, 10 feet; area, 3 square feet; mean velocity, 1.67 feet per second; gage height, 0.10 foot; discharge, 5 second-feet.

November 17: Width, 7 feet; area, 3.8 square feet; mean velocity, 1 foot per second; gage height, 0.10 foot; discharge, 3.8 second-feet.

December 2: Width, 7 feet; area, 4.6 square feet; mean velocity, 1 foot per second; gage height, 0.15 foot; discharge, 4.6 second-foot.

*Tuttle Creek near Lone Pine, Cal.*—This stream is tributary to Owens River from the eastern slope of the Sierra Nevada. The following measurements were made during 1905 at the point where the stream leaves the foothills and enters the valley:

June 16: Width, 12 feet; area, 6 square feet; mean velocity, 1.80 feet per second; discharge, 10.8 second-feet.

July 19: Width, 10 feet; area, 4.5 square feet; mean velocity, 2.40 feet per second; discharge, 10.8 second-feet.

*Tinemaha Creek near Tinemaha, Cal.*—This stream is tributary to Owens River from the eastern slope of the Sierra Nevada. The following measurements were made during 1905 at the point where the stream leaves the foothills and enters the valley:

June 14: Width, 8 feet; area, 10.5 square feet; mean velocity, 1.86 feet per second; discharge, 19.5 second-feet.

July 17: Width, 6 feet; area, 4.4 square feet; mean velocity, 3.36 feet per second; discharge, 14.8 second-feet.

December 2: Width, 7 feet; area, 5.2 square feet; mean velocity, 0.60 foot per second; discharge, 3.1 second-feet.

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## MOHAVE RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

The Mohave River rises on the northern slope of the San Bernardino Mountains, and, flowing in a northerly direction, finally disappears in the sands of the Mohave Desert. This stream has few tributaries, the only ones of importance being West Fork and Deep Creek, which have their source in the higher elevations of the San Bernardino Mountains. The formation is of granite, with good covering of soil. On the higher elevations there is a considerable growth of timber, which diminishes as one approaches the lower reaches, changing to a light growth of brush and grass, finally merging into the barren desert. During the greater portion of the year the stream bed is dry below the junction of West Fork and Deep Creek, where the waters disappear in the sand and gravelly bed of the stream. Water again rises at a point lower down on the river above Victorville, where the gaging station is located. Water is diverted above and below the gaging station, but is again returned to the river channel. There are several artesian wells along the river above the gaging station, the water being used for irrigation. This stream does not discharge in any large quantity except during an extremely heavy rainfall in the winter months. The precipitation throughout this basin is very light, with the possible exception of the higher elevation of the San Bernardino Mountains, where there is a considerable fall of snow during the winter months, which melts in the early spring.

### MOHAVE RIVER AT VICTORVILLE, CAL.

This station was established February 27, 1899, by Bert Cole. It is located in the town of Victorville, a station on the Atchison, Topeka and Santa Fe Railroad, where the Mohave River passes through a narrow gorge locally known as the "Narrows." This place has been under investigation as a possible dam site, and soundings for the depth of bed rock were made by the United States Geological Survey during the season of 1899. The greatest depth of bed rock was found to be 54 feet. The diamond drill showed the rock to be a fine granite. A more detailed account of this exploration will be found in the Twenty-first Annual Report, part 4. Above the "Narrows" the valley broadens into a large reservoir site, but as no surveys of it have been made the capacity is unknown.

The channel is straight for 300 feet above and below the section where the rod is located. Both banks are high and rocky and not subject to overflow. The channel is composed of sand, which is constantly shifting.

During medium and low stages discharge measurements are made from a low foot bridge or by wading. During floods discharge measurements are made from the county bridge. The mean estimated monthly discharge is obtained by averaging the discharge measurements made during the year.

Gage readings were discontinued in 1902. On March 1, 1905, a new inclined rod was fastened to the rock on the left bank about 300 feet above the county bridge. This gage was established as a matter of interest in connection with the discharge of the stream at high stages. There is no relation between gage readings and the discharge, as the bed of the stream is constantly changing at different stages of the river. During 1905 discharge measurements were made twice each week, and the gage was read by P. H. Leahy. The bench mark is a bolt sulphured in solid rock on the left bank, about 15 feet from the Santa Fe Railroad track and 40 feet west of the gage rod. It is 20.45 feet above the datum of the gage. Elevation, 2,726.52 feet above sea level, as established by connection with a standard United States Geological Survey bench mark at Victorville.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 100, and 134 of the United States Geological Survey.

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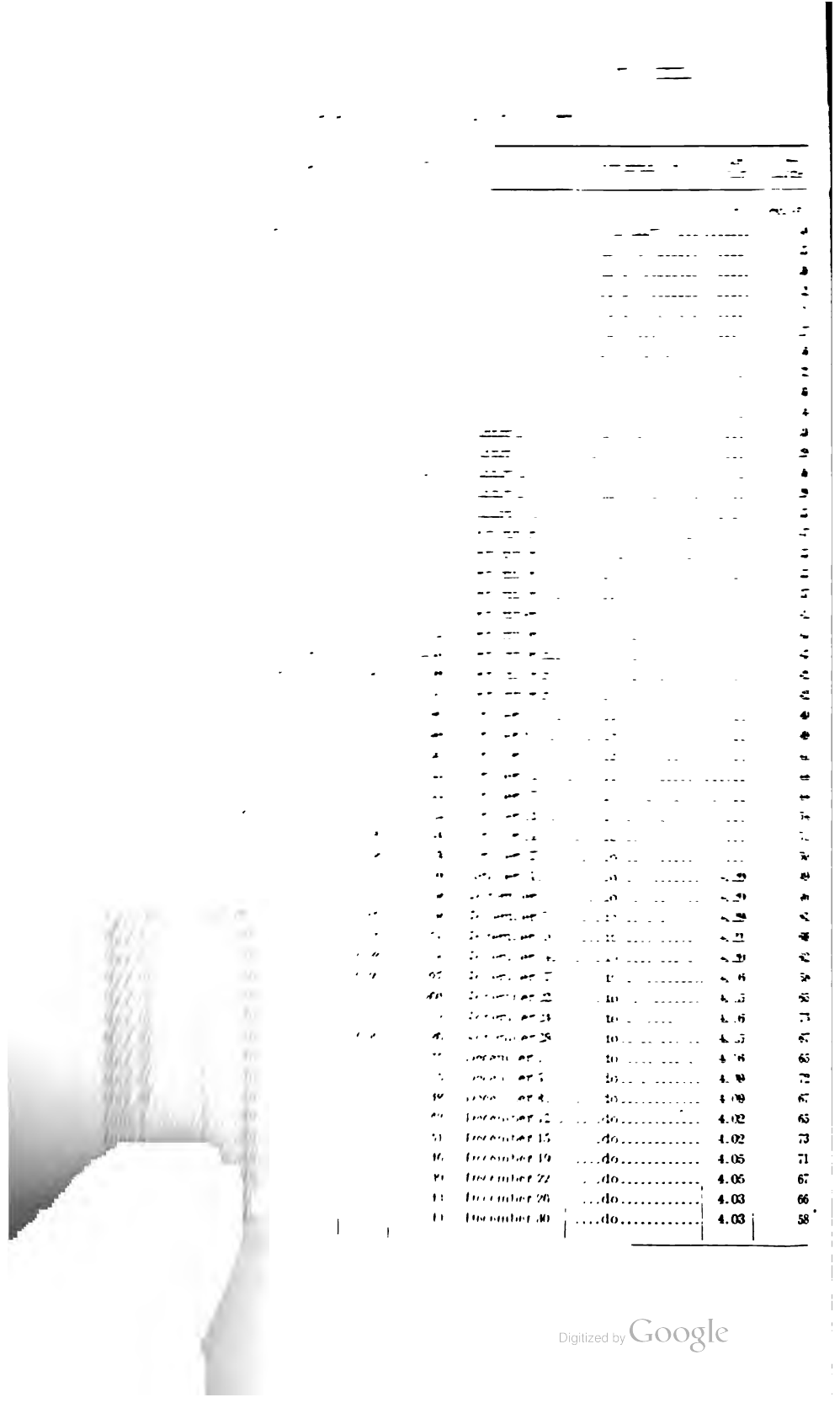

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*Daily gage height, in feet, of Mohave River at Victorville, Cal., for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.0 | 3.9 | 3.45 | 4.0 | 4.05 | 4.0 | 4.0 | 4.1 | 4.2 | 4.15 |
| 2 | 3.95 | 3.9 | 3.5 | 4.0 | 4.0 | 4.0 | 4.0 | 4.1 | 4.2 | 4.15 |
| 3 | ..... | 3.85 | 3.65 | 4.0 | 4.0 | 4.0 | 4.0 | 4.1 | 4.2 | 4.15 |
| 4 | 3.95 | 3.9 | 3.85 | 4.0 | 4.0 | 4.0 | 4.0 | 4.1 | 4.2 | 4.15 |
| 5 | 3.85 | 3.8 | 3.95 | 4.0 | 4.0 | 4.0 | 4.0 | 4.1 | 4.2 | 4.15 |
| 6 | 3.85 | 3.75 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.15 | 4.2 | 4.1 |
| 7 | 3.8 | 3.75 | 4.85 | 4.0 | 4.0 | 4.0 | 4.0 | 4.15 | 4.3 | 4.1 |
| 8 | 3.8 | 3.4 | 4.85 | 4.0 | 4.0 | 4.0 | 4.0 | 4.15 | 4.3 | 4.1 |
| 9 | 3.8 | 3.4 | ..... | 4.0 | 4.0 | 4.0 | 4.0 | 4.15 | 4.25 | 4.1 |
| 10 | 3.75 | 3.65 | 4.6 | 4.0 | 4.0 | 4.0 | 4.0 | 4.15 | 4.2 | 4.05 |
| 11 | 3.75 | 3.65 | 4.6 | 4.0 | 4.0 | 4.0 | 4.0 | 4.15 | 4.2 | 4.05 |
| 12 | 3.75 | 3.65 | 4.2 | 4.0 | 4.0 | 4.0 | 4.0 | 4.15 | 4.2 | 4.0 |
| 13 | 9.95 | 3.65 | 4.2 | 4.05 | 4.0 | 4.0 | 4.0 | 4.15 | 4.2 | 4.0 |
| 14 | 5.0 | 3.65 | 4.1 | 4.05 | 4.0 | 4.0 | 4.0 | 4.15 | 4.2 | 4.0 |
| 15 | 5.0 | 3.6 | 4.1 | 4.05 | 4.0 | 4.0 | 4.0 | 4.15 | 4.2 | 4.0 |
| 16 | 5.05 | 3.6 | 4.05 | 4.05 | 4.0 | 4.0 | 4.0 | 4.15 | 4.15 | 4.0 |
| 17 | 4.1 | 3.6 | 4.0 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.0 |
| 18 | 4.05 | 3.6 | 4.0 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.05 |
| 19 | 4.05 | 3.55 | 4.0 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.05 |
| 20 | 4.05 | 3.65 | 4.0 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.05 |
| 21 | 4.05 | 3.6 | 4.0 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.05 |
| 22 | 4.05 | 3.6 | 4.0 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.05 |
| 23 | 4.0 | 3.5 | 4.0 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.05 |
| 24 | 4.0 | 3.5 | 4.0 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.05 |
| 25 | 4.0 | 3.5 | 3.95 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.2 | 4.05 |
| 26 | 4.0 | 3.5 | 3.95 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.2 | 4.05 |
| 27 | 4.0 | 3.45 | 4.0 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.05 |
| 28 | 3.85 | 3.45 | 4.2 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.05 |
| 29 | 3.8 | 3.45 | 4.1 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.05 |
| 30 | 4.2 | 3.45 | 4.1 | 4.05 | 4.0 | 4.0 | 4.0 | 4.2 | 4.15 | 4.05 |
| 31 | 3.9 | ..... | 4.0 | ..... | 4.0 | 4.0 | 4.0 | 4.2 | ..... | 4.05 |



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*Daily discharge, in feet, of Mohave River at Victorville, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 56 | 60 | 100 | 263 | 60 | 61 | 35 | 30 | a 47 | 40 | 48 | a 65 |
| 2 | 56 | 325 | a 98 | 237 | 100 | a 63 | 36 | a 30 | 44 | 40 | 47 | 68 |
| 3 | a 56 | 605 | a 90 | 211 | a 151 | 60 | a 36 | 30 | 41 | a 40 | a 46 | 68 |
| 4 | 57 | 713 | 90 | 185 | 172 | 57 | 35 | 29 | 38 | 40 | 55 | 70 |
| 5 | 58 | a 822 | 91 | 159 | 195 | 54 | 34 | a 29 | a 35 | 44 | 64 | a 72 |
| 6 | a 58 | 576 | a 91 | a 133 | a 218 | a 51 | 33 | 29 | 35 | a 49 | 72 | 67 |
| 7 | 61 | 328 | 88 | 133 | 246 | 50 | a 32 | 29 | 35 | 47 | a 81 | 67 |
| 8 | 64 | a 82 | 84 | a 133 | 272 | 49 | 32 | 29 | a 35 | 45 | 76 | a 67 |
| 9 | 67 | 84 | 81 | 133 | 300 | 47 | 32 | 29 | 35 | 43 | 71 | 67 |
| 10 | a 70 | 87 | 77 | 128 | a 327 | a 46 | 31 | 29 | 36 | a 41 | a 66 | 66 |
| 11 | 70 | a 90 | a 74 | a 123 | 296 | 44 | a 31 | 29 | a 37 | 41 | 65 | 66 |
| 12 | 71 | 90 | 74 | 118 | 273 | 41 | 29 | 29 | 38 | 41 | 64 | a 65 |
| 13 | a 71 | 90 | a5, 410 | 110 | a 260 | a 39 | 28 | 29 | 39 | a 44 | 63 | 67 |
| 14 | 68 | 90 | 2, 295 | a 104 | 224 | 40 | a 27 | 31 | 40 | 44 | a 62 | 70 |
| 15 | 65 | a2, 032 | a 820 | 103 | 188 | 41 | 29 | 31 | a 42 | 44 | 61 | a 73 |
| 16 | 62 | 1, 387 | a2, 250 | 98 | a 152 | a 43 | 31 | 33 | 42 | 44 | 59 | 73 |
| 17 | a 59 | 150 | 1, 665 | 95 | 134 | 43 | 34 | 33 | 42 | a 44 | a 58 | 72 |
| 18 | 59 | a 97 | a 980 | a 93 | 116 | 43 | a 36 | 33 | 42 | 47 | 60 | 71 |
| 19 | 59 | 96 | 920 | 86 | 98 | 43 | 35 | 33 | a 43 | 50 | 61 | a 71 |
| 20 | a 59 | 95 | 860 | 79 | a 80 | a 43 | 33 | 33 | 43 | a 54 | 62 | 70 |
| 21 | 59 | a 95 | 800 | 75 | 75 | 41 | a 32 | 36 | 43 | 53 | 64 | 68 |
| 22 | 59 | 95 | a 740 | 70 | 70 | 39 | 32 | 36 | a 43 | 52 | a 65 | a 67 |
| 23 | 58 | 95 | 647 | 65 | a 65 | 37 | 32 | 36 | 42 | 51 | 69 | 67 |
| 24 | 57 | 95 | 553 | a 60 | 63 | 35 | 31 | 36 | 42 | a 51 | a 73 | 67 |
| 25 | a 56 | 95 | a 460 | a 38 | 60 | 33 | a 30 | a 36 | 42 | 51 | 71 | 67 |
| 26 | 55 | 95 | 450 | 43 | 58 | 31 | 32 | 33 | a 42 | 51 | 70 | a 66 |
| 27 | a 53 | 95 | a 340 | 48 | a 55 | a 30 | 33 | 31 | 42 | a 50 | 69 | 64 |
| 28 | 54 | 95 | 327 | 53 | 52 | 31 | a 34 | a 29 | 42 | 50 | a 67 | 62 |
| 29 | 54 | ..... | 315 | a 58 | a 48 | 33 | 32 | 31 | a 42 | 50 | 67 | 60 |
| 30 | 55 | ..... | 302 | 60 | 53 | a 35 | 32 | 33 | 42 | 49 | 66 | a 58 |
| 31 | a 56 | ..... | 290 | ..... | 57 | ..... | 32 | a 35 | ..... | a 49 | ..... | 58 |

a Taken from discharge measurements.

NOTE.—Daily discharge obtained by interpolation between discharge measurements.

*Estimated monthly discharge of Mohave River at Victorville, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 71 | 53 | 60.1 | 3,695 |
| February | 2,032 | 60 | 309 | 17,160 |
| March | 5,410 | 74 | 695 | 42,734 |
| April | 263 | 38 | 110 | 6,545 |
| May | 327 | 48 | 146 | 8,977 |
| June | 63 | 30 | 43.4 | 2,583 |
| July | 36 | 27 | 32.3 | 1,986 |
| August | 36 | 29 | 31.6 | 1,943 |
| September | 47 | 34 | 40.0 | 2,380 |
| October | 54 | 40 | 46.5 | 2,859 |
| November | 81 | 46 | 64.0 | 3,808 |
| December | 73 | 58 | 67.0 | 4,120 |
| The year | 5,410 | 27 | 137 | 98,790 |

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## SOUTHERN PACIFIC OCEAN DRAINAGE.

### GENERAL FEATURES.

The Southern Pacific Ocean drainage includes those streams south of San Francisco Bay whose waters, in times of flood at least, reach the Pacific Ocean.

### SAN LUIS REY RIVER DRAINAGE BASIN.

#### DESCRIPTION OF BASIN.

The San Luis Rey River rises on the western slope of the Coast Range in the northern portion of San Diego County, and, flowing in a westerly direction, discharges its waters into the Pacific Ocean near the town of Oceanside. It has numerous small tributaries, none of which have their sources at elevations above 5,000 feet. On the upper reaches of this stream the country is rolling, with several small valleys which are under cultivation, being used principally for the raising of grain and the pasturage of stock. At a point below what is known as Warner's ranch reservoir site the river flows through a deep, narrow canyon, with a heavy grade for a distance of about 10 miles, below which point the grade is light and the discharge is over a sandy and gravelly bed, where the water soon disappears, again rising in small quantities near the town of Pala, where the gaging station is located. Below this point it flows for a distance of about 25 miles on a light grade to the Pacific Ocean. There is a good soil covering throughout this basin, with a considerable growth of brush and grass, and with small areas of timber on the extreme higher elevations. The water is diverted at several points along this stream for irrigation, a considerable quantity being diverted from the canyon above the gaging station and used in the vicinity of Escondido, which lies in an entirely separate drainage basin. This stream is torrential in its character, the discharge being very light except during the winter season, in times of heavy rainfall. The mean precipitation varies from 10 to 20 inches and falls principally in the form of rain, there being only a light fall of snow on the extreme higher elevations, which soon melts and only adds to the flood discharge.

#### SAN LUIS REY RIVER NEAR PALA, CAL.

This station was established October 9, 1903, by W. B. Clapp. It is located at Sickler's mill, 4 miles above Pala, Cal. It is reached by driving from Fallbrook or Temecula, stations on the Southern California Railway, 18 and 13 miles distant, respectively.

The channel is straight for about 800 feet above and 2,000 feet below the station. The grade of the stream is 0.60 foot in 100 feet. The current is swift. The right bank rises abruptly about 15 feet beyond the oak tree to which the cable is fastened and is not liable to overflow. The left bank is low, but is not liable to overflow. It was once a portion of the river channel, but is now well above high-water marks. The bed of the stream is rocky in portions of the flood channel, but the low-water channel is clear of rocks. There is a considerable growth of small timber in the channel, but this has been cleared the entire width of the cross section for a distance of 100 feet above and 50 feet below the station. This timber growth is not permanent, being washed out by floods every few years.

Discharge measurements are usually made by wading. During high water they are made from a car suspended from a cable stretched across the river at the gage. The initial point for soundings is the base of the oak tree to which the left end of the cable is fastened.

The gage is an inclined staff fastened to tree stumps and stakes at the left bank of the river. During 1905 the gage was read once each day by M. M. Sickler. The bench mark is a United States standard bronze-capped iron post set flush with the ground on the right bank of the river and the north side of the wagon road, and about 50 feet west from the line of the cable prolonged. Its elevation is 557 feet above mean sea level and 26.98 feet above the datum of the gage.

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Information in regard to this station is contained in Water-Supply Papers Nos. 100 and 134 of the United States Geological Survey.

*Discharge measurements of San Luis Rey River near Pala, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| February 8 | E. C. La Rue | 44 | 43 | 2.51 | 2.25 | 108 |
| February 17 | F. M. Sickler | 51 | 70 | 2.69 | 2.72 | 188 |
| February 18 | do | 100 | 204 | 3.60 | 4.75 | 735 |
| March 17 | do | 188 | 679 | 7.14 | 7.50 | 5,180 |
| March 22 | R. S. Hawley | 67 | 100 | 3.05 | 2.64 | 305 |
| March 22 | F. M. Sickler | 68 | 96 | 3.11 | 2.64 | 299 |
| April 11 | do | 44 | 42 | 2.48 | 1.80 | 104 |
| May 15 | do | 41 | 26 | 1.88 | 1.20 | 49 |
| May 17 | do | 40 | 21 | 1.90 | 1.10 | 40 |
| May 20 | do | 43 | 25 | 2.28 | 1.40 | 57 |
| July 6 | do | 3.0 | 1.7 | 2.06 | .55 | 3.5 |
| August 8 | R. S. Hawley | 3.6 | 1.7 | 1.74 | (a) | 3 |
| August 19 | M. M. Sickler | 3.5 | 1.6 | 2.00 | ..... | 3.2 |
| August 26 | do | 3.5 | 1.6 | 2.06 | ..... | 3.3 |
| September 2 | do | 3.5 | 1.5 | 1.80 | ..... | 2.7 |
| September 9 | do | 3.5 | 1.5 | 1.80 | ..... | 2.7 |
| September 16 | do | 3.5 | 1.4 | 1.78 | ..... | 2.5 |
| September 21 | D. W. Murphy | ..... | ..... | ..... | ..... | 2.1 |
| September 23 | F. M. Sickler | 3.5 | 1.4 | 2.00 | .42 | 2.8 |
| October 28 | do | 3.5 | 1.6 | 2.25 | .53 | 3.6 |
| December 27 | do | 7 | 4.1 | 3.15 | .63 | 12.9 |
| December 29 | do | 10.9 | 6.7 | 1.40 | .61 | 9.4 |

(a) Channel so uncertain from July 11 to September 23 that no readings were made.

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*Estimated monthly discharge of San Luis Rey River near Pala, Cal., for 1903–1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| 1903. | | | | |
| October (23 days) | 1.5 | 1.0 | 1.1 | 50 |
| November | 1.5 | 1.0 | 1.4 | 83 |
| December | 1.5 | 1.0 | 1.2 | 74 |
| The period | | | | 207 |
| 1904. | | | | |
| January | 1.5 | 1.5 | 1.5 | 92 |
| February | 2.5 | 1.5 | 2.0 | 115 |
| March | 348 | 1.5 | 41.6 | 2,558 |
| April | 104 | 20 | 43.6 | 2,595 |
| May | 35 | 12 | 16.2 | 996 |
| June | 12 | 9 | 10.8 | 643 |
| July | 9 | 3 | 3.8 | 234 |
| August | 2 | 2 | 2.0 | 123 |
| September | 2 | 2 | 2.0 | 119 |
| October | 13 | 2 | 2.5 | 154 |
| November | 3 | 2 | 2.4 | 143 |
| December | 5.5 | 2 | 3.7 | 227 |
| The year | 348 | 1.5 | 11.0 | 7,999 |
| 1905. | | | | |
| January | 66 | 3 | 19.1 | 1,174 |
| February | 711 | 13 | 151 | 8,386 |
| March | 4,265 | 2 | 336 | 20,660 |
| April | 139 | 27 | 64.9 | 3,862 |
| May | 282 | 27 | 88.1 | 5,417 |
| June | 35 | 11 | 23 | 1,369 |
| July | 9 | 3 | 4.1 | 252 |
| August | 3.5 | 3 | 3 | 184 |
| September | 3.0 | 2.5 | 2.6 | 155 |
| October | 3.8 | 2.8 | 3.2 | 197 |
| November | 96.0 | 3.8 | 17.8 | 1,059 |
| December | 47.0 | 10 | 18.3 | 1,125 |
| The year | 4,265 | 2.0 | 60.9 | 43,840 |

NOTE.—The estimated monthly discharge is approximate only.

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## SANTA ANA RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Santa Ana River has its source in the southern slope of the San Bernardino Mountains and, flowing in a southwesterly direction, traverses San Bernardino Valley, below which it breaks in a narrow canyon through the Santa Ana Mountains, finally discharging its waters through Santa Ana Valley into the Pacific Ocean below the town of Santa Ana. This stream has numerous tributaries which rise in the southern slope of the San Bernardino Mountains, the surface flow of most of which only reach Santa Ana River, where it traverses San Bernardino Valley in times of flood discharge. The topography on the higher elevations is rough and rugged, reaching elevations of from 10,000 to 12,000 feet, the formation being of granite with good soil covering and considerable growth of timber. On the lower elevations the topography is less rough and the soil covering is principally of brush. A gaging station is located on this stream at a point known as Warm Springs, a distance of about 8 miles above Redlands. Below this station the river leaves the mountainous country and discharges over a sandy and gravelly bed through San Bernardino Valley. During the summer months the entire flow of the stream is diverted above this gaging station and used for power development at the mouth of the canyon, below which point it is again taken out and used for irrigation on the higher elevations of San Bernardino Valley along the base of the mountains where the country is under a high state of cultivation, used principally for the raising of citrus fruits. The water rises to the surface in San Bernardino Valley near the city of San Bernardino and is diverted and used extensively for irrigation in the neighborhood of Riverside. In addition to this surface flow a large number of wells have been sunk in this territory, many of which are artesian, and from others the water is being pumped. This developed water is also used extensively for irrigation in the vicinity of San Bernardino and Riverside. The water is again forced to the surface by bed-rock obstructions at Riverside Narrows below the city of Riverside, and gradually increases in volume until it reaches Santa Ana Canyon, where it is diverted for irrigation on the lower valley lands in the vicinity of Santa Ana and Fullerton. During the summer months measurements are made of the flow at Rincon, Cal., at the head of Santa Ana Canyon. There are only occasional flood discharges of this river which flow continuously from the mountain to the sea. The mean precipitation throughout this basin is from 15 to 30 inches, which falls in the form of rain except on the higher elevations of the San Bernardino Mountains, where there is a considerable snowfall, which usually remains on the extreme high elevations until midsummer. A storage reservoir has been constructed on Bear Creek, a tributary of this stream, and is known as the Bear Valley reservoir. This stored water is held until the summer months and used for irrigation in San Bernardino Valley.

### SANTA ANA RIVER NEAR MENTONE, CAL.

This station was established in June, 1896. It is located 5 miles northeast of Mentone, Cal., three-fourths of a mile below the headworks of the Mentone Power Company's canal, and opposite the warm springs in the canyon.

The Edison Electric Company diverts the greater portion of the water from Santa Ana River above the gaging station, but also returns all of it above the station. They, however, allow only limited portions of the water to pass out of their conduits during certain hours of the day, holding back the water for the purpose of obtaining additional power when the greatest demand exists.

The Mentone Power Company's canal, formerly called the Santa Ana canal, diverts water above the station, all of which is returned below the point of measurement. During the low-water season the entire flow of the river is diverted by the canals.

The channel is straight for 100 feet above and below the station, and has a width of 22 feet at low and 125 feet at high stages. The current is swift at all stages. The right bank is low and is liable to overflow at flood stages for about 100 feet. The left bank is low but is

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not liable to overflow. Both banks are overgrown with alders. The bed of the stream is composed of firm sand and small bowlders. It is subject to considerable change during flood stages.

Discharge measurements are made by means of a cable and car. The initial point for soundings is the bench-mark spike set in the north side of a cottonwood tree on the left bank, 30 feet west of the tree to which the cable is fastened. At flood stages the velocity is so high that measurements can be made only by means of floats.

The gage is an inclined timber fastened to a large bowlder on the left bank 100 feet above the cable. The channel was deepened by a flood March 31, 1903, and the gage was accordingly lowered to reach low-water stages June 30, 1903. During 1905 the gage was read once each day by A. Laird. The bench mark is a spike in the north side of the cottonwood tree on the left bank, 30 feet west of the tree to which the cable is fastened; elevation, 7.29 feet above the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 100, and 134 of the United States Geological Survey.

*Discharge measurements of Santa Ana River near Mentone, Cal., in 1905.*

| Date. | Hydrographer. | Gage height of river. | Discharge. | | |
|---|---|---|---|---|---|
| | | | River. | Mentone Power Company's canal. | Total for River. |
| | | *Feet.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* |
| February 13 | Clapp and La Rue | 1.15 | 10 | 40 | 50 |
| February 21 | E. C. La Rue | 1.70 | 17 | 74 | 91 |
| February 22 | do | 1.65 | 10 | 71 | 81 |
| February 23 | do | 1.65 | 11 | 63 | 74 |
| March 14 a. m | do | 2.60 | 188 | 0 | 188 |
| March 14 p. m | do | 2.50 | 138 | 50 | 188 |
| March 15 a. m | do | 2.30 | 132 | 57 | 189 |
| March 15 p. m | do | 2.10 | 113 | 57 | 170 |
| March 30 | R. S. Hawley | 1.90 | 81 | 46 | 127 |
| April 14, 1 p. m | do | 1.95 | 86 | 1 | 87 |
| May 17 | do | 2.25 | 111 | 37 | 148 |
| June 7 | do | 2.20 | 79 | 0 | 79 |
| June 26 | do | 1.43 | 4 | 66 | 70 |
| July 6 | do | 1.40 | 3 | 61 | 64 |

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*Daily gage height, in feet, of Santa Ana River near Mentone, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.85 | 0.8 | 1.3 | 1.7 | 1.3 | 2.3 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.5 |
| 2 | .85 | 2.5 | 1.3 | 2.05 | 2.2 | 2.3 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.5 |
| 3 | .85 | 2.3 | 1.3 | 2.05 | 2.0 | 2.3 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 4 | .85 | 2.8 | 1.3 | 1.35 | 2.0 | 2.3 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 5 | .85 | 3.0 | 1.3 | 1.35 | 1.9 | 2.3 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 6 | .85 | 1.9 | 1.25 | 1.35 | 1.9 | 2.25 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 7 | .85 | 1.9 | 1.25 | 1.35 | 2.0 | 2.25 | 1.4 | 1.3 | 1.3 | 1.3 | 1.35 | 1.4 |
| 8 | .85 | 1.75 | 1.25 | 1.35 | 2.3 | 2.2 | 1.4 | 1.3 | 1.3 | 1.3 | 1.4 | 1.4 |
| 9 | 2.0 | 1.5 | 1.25 | 1.35 | 2.2 | 2.2 | 1.4 | 1.3 | 1.3 | 1.3 | 1.35 | 1.4 |
| 10 | 1.0 | 1.5 | 1.25 | 1.35 | 2.2 | 2.2 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 11 | .85 | 1.35 | 1.25 | 1.35 | 2.2 | 2.15 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 12 | .85 | 1.25 | 1.3 | 1.35 | 2.2 | 1.6 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 13 | .85 | 1.15 | 3.4 | 1.3 | 2.2 | 1.75 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 14 | .85 | 1.1 | 2.6 | 1.3 | 2.5 | 1.6 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 15 | .85 | 1.1 | 2.35 | 1.3 | 2.5 | 1.45 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 16 | .8 | 2.8 | 2.4 | 1.3 | 2.6 | 1.45 | 1.35 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 17 | .8 | 2.1 | 2.5 | 2.2 | 2.6 | 1.6 | 1.35 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 18 | .8 | 1.9 | 2.6 | 2.0 | 2.5 | 1.6 | 1.35 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 |
| 19 | .8 | 1.9 | 2.5 | 2.1 | 2.6 | 1.55 | 1.35 | 1.3 | 1.3 | 1.3 | 1.35 | 1.6 |
| 20 | .8 | 1.8 | 2.6 | 1.2 | 2.6 | 1.55 | 1.35 | 1.3 | 1.3 | 1.3 | 1.35 | 2.2 |
| 21 | 1.65 | 1.7 | 2.5 | 1.15 | 2.5 | 1.45 | 1.35 | 1.3 | 1.3 | 1.3 | 1.4 | 1.6 |
| 22 | .85 | 1.7 | 2.4 | 1.2 | 2.2 | 1.45 | 1.35 | 1.3 | 1.3 | 1.3 | 1.35 | 1.5 |
| 23 | .85 | 1.5 | 2.0 | 1.4 | 2.2 | 1.45 | 1.35 | 1.3 | 1.3 | 1.3 | 1.35 | 1.5 |
| 24 | .85 | 1.3 | 1.9 | 1.4 | 2.1 | 1.45 | 1.3 | 1.3 | 1.3 | 1.3 | 1.35 | 1.5 |
| 25 | .85 | 1.85 | 1.9 | 1.3 | 2.3 | 1.45 | 1.3 | 1.3 | 1.3 | 1.3 | 1.35 | 1.5 |
| 26 | .85 | 1.25 | 1.9 | 1.3 | 2.2 | 1.45 | 1.3 | 1.3 | 1.3 | 1.3 | 1.8 | 1.5 |
| 27 | .85 | 1.35 | 1.8 | 1.3 | 2.2 | 1.45 | 1.3 | 1.3 | 1.3 | 1.3 | 2.5 | 1.5 |
| 28 | .85 | 1.3 | 1.65 | 1.25 | 2.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 2.9 | 1.5 |
| 29 | .8 | ..... | 1.5 | 1.2 | 2.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.7 | 2.0 |
| 30 | .8 | ..... | 2.0 | 1.2 | 2.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.5 | 1.6 |
| 31 | .8 | ..... | 1.8 | ..... | 2.4 | ..... | 1.3 | 1.3 | ..... | 1.3 | ..... | 1.5 |

*Station rating table for Santa Ana River near Mentone, Cal., from January 1 to February 17, 1905.*

| Gage height. | Discharge | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.80 | 1 | 1.40 | 23 | 2.00 | 80 | 2.60 | 170 |
| 0.90 | 2 | 1.50 | 29 | 2.10 | 93 | 2.70 | 186 |
| 1.00 | 5 | 1.60 | 37 | 2.20 | 106 | 2.80 | 202 |
| 1.10 | 8 | 1.70 | 47 | 2.30 | 122 | 2.90 | 218 |
| 1.20 | 12 | 1.80 | 57 | 2.40 | 138 | 3.00 | 234 |
| 1.30 | 17 | 1.90 | 68 | 2.50 | 154 | | |

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*Station rating table for Santa Ana River near Mentone, Cal., from February 18 to March 12 and from June 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.30 | 1 | 2.00 | 48 | 2.70 | 164 | 3.40 | 290 |
| 1.40 | 3 | 2.10 | 62 | 2.80 | 182 | 3.50 | 308 |
| 1.50 | 6 | 2.20 | 78 | 2.90 | 200 | 3.60 | 326 |
| 1.60 | 11 | 2.30 | 94 | 3.00 | 218 | 3.70 | 344 |
| 1.70 | 17 | 2.40 | 110 | 3.10 | 236 | 3.80 | 362 |
| 1.80 | 25 | 2.50 | 128 | 3.20 | 254 | 3.90 | 380 |
| 1.90 | 35 | 2.60 | 146 | 3.30 | 272 | | |

*Station rating table for Santa Ana River near Mentone, Cal., from March 13 to May 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.80 | 1 | 1.60 | 46 | 2.40 | 151 | 3.20 | 287 |
| 0.90 | 2 | 1.70 | 56 | 2.50 | 168 | 3.30 | 304 |
| 1.00 | 4 | 1.80 | 68 | 2.60 | 185 | 3.40 | 321 |
| 1.10 | 8 | 1.90 | 80 | 2.70 | 202 | 3.50 | 338 |
| 1.20 | 13 | 2.00 | 92 | 2.80 | 219 | 3.60 | 355 |
| 1.30 | 20 | 2.10 | 106 | 2.90 | 236 | 3.70 | 362 |
| 1.40 | 28 | 2.20 | 120 | 3.00 | 253 | 3.80 | 379 |
| 1.50 | 36 | 2.30 | 135 | 3.10 | 270 | | |

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*Daily discharge, in second-feet, of Santa Ana canal near Mentone, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22 | 25 | 60 | 57 | 71 | 0 | 63 | 53 | 66 | 51 | 46 | 34 |
| 2 | 22 | 64 | 57 | 0 | 66 | 0 | 61 | 53 | 63 | 51 | 32 | 32 |
| 3 | 21 | 64 | 60 | 0 | 66 | 0 | 61 | 51 | 63 | 56 | 32 | 34 |
| 4 | 21 | 0 | 60 | 54 | 56 | 0 | 61 | 61 | 63 | 56 | 32 | 32 |
| 5 | 21 | 0 | 60 | 63 | 58 | 0 | 61 | 61 | 66 | 51 | 32 | 32 |
| 6 | 22 | 22 | 57 | 63 | 73 | 0 | 61 | 61 | 66 | 46 | 36 | 32 |
| 7 | 21 | 42 | 57 | 63 | 51 | 0 | 58 | 63 | 66 | 46 | 41 | 32 |
| 8 | 20 | 37 | 54 | 72 | 56 | 0 | 58 | 63 | 61 | 41 | 46 | 32 |
| 9 | 0 | 37 | 51 | 78 | 66 | 0 | 56 | 63 | 61 | 56 | 41 | 32 |
| 10 | 61 | 35 | 48 | 78 | 76 | 0 | 56 | 63 | 63 | 46 | 29 | 30 |
| 11 | 54 | 43 | 48 | 72 | 76 | 0 | 58 | 63 | 73 | 46 | 29 | 32 |
| 12 | 41 | 26 | 51 | 66 | 76 | 66 | 61 | 63 | 76 | 61 | 30 | 32 |
| 13 | 41 | 28 | 0 | 66 | 76 | 43 | 63 | 66 | 76 | 66 | 32 | 29 |
| 14 | 31 | 29 | 0 | 63 | 0 | 71 | 66 | 68 | 78 | 56 | 30 | 29 |
| 15 | 31 | 35 | 0 | 57 | 0 | 71 | 66 | 68 | 78 | 61 | 30 | 32 |
| 16 | 27 | 29 | 97 | 43 | 71 | 71 | 63 | 71 | 78 | 56 | 29 | 30 |
| 17 | 29 | 32 | 78 | 0 | 71 | 68 | 63 | 71 | 78 | 51 | 29 | 30 |
| 18 | 33 | 42 | 0 | 0 | 71 | 68 | 63 | 81 | 78 | 46 | 29 | 29 |
| 19 | 25 | 70 | 0 | 0 | 36 | 68 | 61 | 81 | 73 | 43 | 29 | 29 |
| 20 | 27 | 70 | 0 | 71 | 36 | 68 | 61 | 56 | 68 | 41 | 29 | 29 |
| 21 | 66 | 70 | 0 | 66 | 32 | 68 | 61 | 56 | 68 | 41 | 34 | 32 |
| 22 | 61 | 74 | 78 | 66 | 29 | 68 | 61 | 56 | 61 | 46 | 32 | 25 |
| 23 | 49 | 74 | 66 | 66 | 29 | 68 | 61 | 56 | 68 | 41 | 30 | 25 |
| 24 | 40 | 66 | 78 | 66 | 29 | 68 | 61 | 73 | 68 | 41 | 29 | 25 |
| 25 | 31 | 66 | 78 | 71 | 0 | 68 | 61 | 73 | 51 | 46 | 30 | 25 |
| 26 | 29 | 58 | 60 | 71 | 0 | 68 | 61 | 73 | 56 | 46 | 30 | 25 |
| 27 | 27 | 51 | 85 | 66 | 0 | 68 | 61 | 76 | 56 | 41 | 41 | 29 |
| 28 | 25 | 58 | 85 | 66 | 0 | 63 | 61 | 76 | 66 | 41 | 50 | 28 |
| 29 | 25 | ..... | 78 | 71 | 0 | 63 | 61 | 76 | 66 | 41 | 41 | 30 |
| 30 | 25 | ..... | 42 | 76 | 0 | 63 | 56 | 73 | 66 | 41 | 32 | 29 |
| 31 | 25 | ..... | 57 | ..... | 0 | ..... | 56 | 73 | ..... | 41 | ..... | 27 |

*Estimated monthly discharge of Santa Ana a River near Mentone, Cal., for 1905.*

[Drainage area, 182 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 108 | 22 | 36.6 | 2,251 | 0.201 | 0.232 |
| February | 234 | 26 | 97.6 | 5,420 | .536 | .558 |
| March | 321 | 48 | 130 | 7,993 | .714 | .823 |
| April | 120 | 63 | 90.5 | 5,385 | .497 | .554 |
| May | 256 | 91 | 172 | 10,580 | .945 | 1.09 |
| June | 94 | 64 | 77.7 | 4,624 | .427 | .476 |
| July | 69 | 57 | 62.9 | 3,867 | .346 | .399 |
| August | 82 | 52 | 66.8 | 4,107 | .367 | .423 |
| September | 79 | 52 | 68.3 | 4,064 | .375 | .418 |
| October | 67 | 42 | 49.2 | 3,025 | .270 | .311 |
| November | 250 | 30 | 47.5 | 2,827 | .261 | .291 |
| December | 107 | 31 | 38.4 | 2,362 | .211 | .243 |
| The year | 321 | 22 | 78.1 | 56,500 | .429 | 5.82 |

a Including Mentone Power Company's canal.

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### SEEPAGE MEASUREMENTS.

In the vicinity of Colton and San Bernardino large quantities of water are developed in addition to the natural surface flow. This water is used for the irrigation of land in the vicinity of San Bernardino, Colton, and Riverside, and also for domestic supply for these towns. Much of this water returns to Santa Ana River below Riverside, above a point known as Slover Mountain and is again diverted and used for irrigation on the lower lands below Riverside, and above what is known as Riverside Narrows. Below this point there are still further diversions which irrigate the lower lands along the river bottom, much of this water again returning to the river above Rincon. Measurements were made during the summer of 1905 to determine the amount of water, including the natural flow and developed water, above Colton, Cal. Also measurements were made of natural flow and developed water below Slover Mountain and above Riverside Narrows, this all being return water from irrigated lands on the higher elevations. Measurements were also made of diversion ditches and Santa Ana River below Riverside Narrows and above what is known as the Auburndale Bridge. The following tabulations show the result of these measurements which were made by K. Sanborn, of Riverside, Cal.

*Natural flow of return water to Santa Ana River in second-feet, compared with developed water in San Bernardino Valley above Colton, Cal., 1905.*

[Measurements by K. Sanborn, engineer Riverside Water Company.]

| Date. | Location. | Developed. | Natural. | Total. |
|---|---|---|---|---|
| | | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* |
| June 9 | Barnhill pumping plant | 1.10 | | 1.10 |
| September 27 | do | .80 | | .80 |
| June 10 | Beam ditch | | 0.00 | .00 |
| September 2 | do | | .00 | .00 |
| June 16 | Bloomington pumping plants | 6.62 | | 6.62 |
| September 27 | do | 7.20 | | 7.20 |
| June 10 | City of San Bernardino, Sixth street pumping plant | 1.99 | | 1.99 |
| September 27 | do | 4.80 | | 4.80 |
| June 19 | City of San Bernardino, Lytle Creek | | 2.04 | 2.04 |
| September 27 | do | | 1.90 | 1.90 |
| June 9 | City of Colton pumping plant (total) | 3.81 | | 3.81 |
| September 27 | City of Colton (water used for irrigation) | 1.20 | | 1.20 |
| September 27 | City of Colton pumping plant (total) | 2.70 | | 2.70 |
| May 31 | Camp Carlton ditch | 2.60 | | 2.60 |
| August 14 | do | 1.20 | | 1.20 |
| June 10 | Carr pumping plant | .72 | | .72 |
| August 14 | do | .60 | | .60 |
| June 10 | Daley ditch | | .00 | .00 |
| September 4 | do | | .00 | .00 |
| May 30 | Excelsior Land and Water Co | .65 | | .65 |
| September 28 | do | .40 | | .40 |
| May 31 | Grand Terrace Pumping Co. pumping plant | .54 | | .54 |
| August 14 | do | .00 | | .00 |
| May 31 | Gage canal, Palm avenue weir | 28.83 | | 28.83 |
| September 2 | do | 32.70 | | 32.70 |
| May 26 | Gage canal intake, Santa Ana River | | .00 | .00 |
| September 4 | do | | .00 | .00 |
| June 2 | Haws & Talmadge ditch | | .00 | .00 |
| September 5 | do | | .00 | .00 |
| June 6 | Hunter pumping plant | 1.09 | | 1.09 |
| September 4 | do | 1.60 | | 1.60 |
| June 9 | Johnson & Hubbard pumping plant | .59 | | .59 |

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*Natural flow of return water to Santa Ana River in second-feet, compared with developed water in San Bernardino Valley above Colton, Cal., 1905*—Continued.

| Date. | Location. | Developed. | Natural. | Total. |
|---|---|---|---|---|
| | | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* |
| September 4... | Johnson & Hubbard pumying plant | 0.30 | ..... | 0.30 |
| June 9..... | Lamb pumping plant | .30 | ..... | .30 |
| September 27.. | .....do | .00 | ..... | .00 |
| June 9..... | Lawson Well Co. pumping plant | .62 | ..... | .62 |
| September 27.. | .....do | .60 | ..... | .60 |
| June 10..... | Logsdon & Farrell ditch | ..... | 0.00 | .00 |
| September 2... | .....do | ..... | .00 | .00 |
| June 10..... | Lytle Creek Water and Improvement Co | .00 | ..... | .00 |
| September 27.. | .....do | .00 | ..... | .00 |
| May 30..... | Merryfield pumping plant | .67 | ..... | .67 |
| September 28.. | .....do | .40 | ..... | .40 |
| June 2..... | McKenzie ditch | ..... | .00 | .00 |
| September 5... | .....do | ..... | .00 | .00 |
| June 9..... | Meeks & Daley ditch | ..... | 15.70 | 15.70 |
| September 2... | .....do | ..... | 15.50 | 15.50 |
| June 16..... | McIntyre ditch | ..... | .00 | .00 |
| September 28.. | .....do | ..... | .00 | .00 |
| June 9..... | Orange Land and Water Co. pumping plant | .00 | ..... | .00 |
| September 27.. | .....do | 1.60 | ..... | 1.60 |
| June 16..... | Riverside Highland Water Co., Lytle Creek | 7.05 | ..... | 7.05 |
| September 28.. | .....do | 8.00 | ..... | 8.00 |
| May 31..... | Riverside Highland Water Co., Santa Ana River... | 6.36 | ..... | 6.36 |
| September 4... | .....do | 7.60 | .40 | 8.00 |
| June 16..... | Rancheria pumping plant | 1.24 | ..... | 1.24 |
| September 27.. | .....do | 1.10 | ..... | 1.10 |
| June 2..... | Rabel ditch | ..... | .00 | .00 |
| September 5... | .....do | ..... | .00 | .00 |
| May 31..... | Riverside Water Co., upper canal | 25.33 | 24.85 | 50.18 |
| August 31..... | .....do | 21.20 | 12.90 | 34.10 |
| May 31..... | Riverside Water Co., mill pumping plant | .92 | ..... | .92 |
| August 31..... | .....do | 1.30 | ..... | 1.30 |
| May 31..... | Riverside Water Co., mill flume | ..... | 2.24 | 2.24 |
| August 31..... | .....do | ..... | .00 | .00 |
| May 26..... | Riverside Water Co., flume pump No. 1 | 3.95 | ..... | 3.95 |
| August 31..... | .....do | 3.60 | ..... | 3.60 |
| May 26..... | Riverside Water Co., flume pump No. 2 | 3.18 | ..... | 3.18 |
| August 31..... | .....do | 3.00 | ..... | 3.00 |
| June 6..... | Rosedale Water Co. pumping plant | .30 | ..... | .30 |
| September 28.. | .....do | .00 | ..... | .00 |
| June 6..... | Rogers pumping plant | ..... | .00 | .00 |
| August 31..... | .....do | .00 | ..... | .00 |
| June 2..... | Shay or Stout Dam ditch | ..... | .00 | .00 |
| September 5... | .....do | ..... | .00 | .00 |
| May 31..... | Swamp ditch | ..... | .47 | .47 |
| August 14..... | .....do | ..... | .40 | .40 |
| June 6..... | West Riverside 350-inch Water Co. pumping plant | 2.00 | ..... | 2.00 |
| September 28.. | .....do | 5.60 | ..... | 5.60 |
| June 19..... | Whitlock ditch | ..... | .00 | .00 |
| September 2... | .....do | ..... | .00 | .00 |
| June 6..... | Whiting ditch | ..... | .00 | .00 |
| September 4... | .....do | ..... | .00 | .00 |
| May 31..... | Ward and Warren ditch | .00 | ..... | .00 |
| September 4... | .....do | ..... | .00 | .00 |

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*Return waters in San Bernardino Valley below Slover Mountain and above Riverside Narrows, 1905.*

[Measurements by K. Sanborn, engineer Riverside Water Company.]

| Date. | Location. | Developed. | Natural. | Total. |
|---|---|---|---|---|
| | | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* |
| May 27 | Alvitrez ditch at headgate, east end of West Riverside Bridge. | | 3.00 | 3.00 |
| August 11 | do | | 1.30 | 1.30 |
| June 6 | Cuttle's pumping plant | 2.50 | | 2.50 |
| October 4 | do | 2.25 | | 2.25 |
| May 27 | Evans Island or Jansen ditch, under west end of West Riverside Bridge. | | .00 | .00 |
| August 11 | do | | .00 | .00 |
| May 29 | Evans ditch, near Riverside County line | | .00 | .00 |
| August 11 | do | | .50 | .50 |
| May 29 | Evans Well ditch, Santa Ana street | .00 | | .00 |
| August 9 | do | 1.70 | | 1.70 |
| May 30 | Evans pipe line to China garden at headworks | | .00 | .00 |
| August 11 | do | | .00 | .00 |
| May 27 | Evans pumping plant, 1,000 feet south of west end of West Riverside Bridge. | 2.87 | | 2.87 |
| September 5 | do | 4.20 | | 4.20 |
| June 19 | Evans Jurupa pumping plant at wier end of main | 2.00 | | 2.00 |
| October 4 | Evans Jurupa pumping plant | .00 | | .00 |
| May 30 | Ferris Gallagher ditch, near headworks | | 2.20 | 2.20 |
| August 14 | do | | 2.00 | 2.00 |
| May 30 | Gallagher ditch, near headworks | | .00 | .00 |
| August 14 | do | | 1.20 | 1.20 |
| May 29 | Jurupa pumping plant, to supply Rubidoux ditch | 2.10 | | 2.10 |
| August 15 | do | 4.80 | | 4.80 |
| May 30 | Lower Canal Riverside Water Co. at flume at headworks. | | 2.20 | 2.20 |
| September 5 | do | | .00 | .00 |
| June 6 | Pond's pumping plant | 2.50 | | 2.50 |
| October 4 | do | 2.25 | | 2.25 |
| May 29 | Rubidoux ditch at measuring box | | 4.92 | 4.92 |
| August 15 | do | | 7.20 | 7.20 |
| June 15 | Riverside Power Co. canal at Pedley crossing | | 30.60 | 30.60 |
| September 22 | do | | 27.00 | 27.00 |
| June 19 | Rivero Land Co. pumping plant | .80 | | .80 |
| October 4 | do | .60 | | .60 |
| May 29 | Smith or Evans ditch, 1 mile below Riverside County line. | | 2.30 | 2.30 |
| August 14 | do | | .00 | .00 |
| May 27 | Soquel ditch at intake | | 3.20 | 3.20 |
| August 11 | do | | 2.70 | 2.70 |
| May 27 | Spring Brook pumping plant at wier end of main | | 5.58 | 5.58 |
| August 11 | do | | 3.60 | 3.60 |
| May 29 | Spanishtown pumping plant at wier end of main | 4.17 | | 4.17 |
| August 11 | do | 2.60 | | 2.60 |
| May 30 | Zimmerman pipe line at dam | | 1.40 | 1.40 |
| August 14 | do | | 1.20 | 1.20 |

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*Discharge measurements of canals between the Riverside Narrows and the Auburndale bridge having their source in the Santa Ana River, 1905.*

| Date. | Location. | Discharge. |
|---|---|---|
| | | *Sec.-ft.* |
| June 15 | Castle ditch near intake | 0.00 |
| September 22 | ....do | .00 |
| June 15 | Durkee ditch at Auburndale road crossing | 4.10 |
| September 22 | ....do | .00 |
| June 15 | Fuller ditch at waste gate | 5.60 |
| September 22 | ....do | 5.40 |
| June 15 | Gilliland ditch at Auburndale road crossing | 1.40 |
| September 22 | ....do | .30 |
| June 15 | Newton ditch near intake | 2.30 |
| September 22 | ....do | 1.70 |
| June 15 | Newberry ditch at Auburndale road crossing | .00 |
| September 22 | ....do | .00 |
| June 15 | Roberts or Le Gay ditch near intake Santa Ana River | 1.00 |
| September 22 | ....do | 1.70 |
| June 15 | Wilbur ditch at Rogers pipe trestle crossing Santa Ana River | 6.10 |
| September 22 | ....do | 6.40 |
| June 15 | Santa Ana River, Auburndale Bridge | 63.60 |
| Do | Santa Ana River, Auburndale Bridge, including ditches | 71.13 |
| September 22 | Santa Ana River, Auburndale Bridge | 57.00 |
| Do | Santa Ana River, Auburndale Bridge, including ditches | 57.80 |

## MISCELLANEOUS MEASUREMENTS IN SANTA ANA RIVER DRAINAGE BASIN.

The following is a list of miscellaneous discharge measurements made in the Santa Ana River drainage basin during 1905:

*City Creek near Highlands, Cal.*—This stream is a tributary of Santa Ana River. A measurement was made September 23 by W. B. Clapp in diversion canal at mouth of canyon Measurement made over weir.

Discharge, 1.16 second-feet.

*Chino Creek near Rincon, Cal.*—This stream is a tributary of Santa Ana River. The following measurements were made during 1905 at the wagon bridge at Rincon road crossing, one-fourth mile above junction of Chino Creek with the Santa Ana river.

February 24: Width, 16 feet; area, 22 square feet; mean velocity, 2.09 feet per second; discharge, 46 second-feet.

April 17: Width, 7 feet; area, 5.6 square feet; mean velocity, 4.64 feet per second; discharge, 26 second-feet.

May 16: Width, 5 feet; area, 4 square feet; mean velocity, 4.25 feet per second; discharge, 17 second-feet.

June 6: Width, 4 feet; area, 1.7 square feet; mean velocity, 3.53 feet per second; discharge, 6.0 second-feet.

July 29: Width, 2 feet; area, 0.4 square foot; mean velocity, 2.75 feet per second; discharge, 1.1 second-feet.

September 21: Width, 3 feet; area, 2 square feet; mean velocity, 0.95 foot per second; discharge, 1.9 second-feet.

*Cable Canyon Creek near Glen Helen, Cal.*—This stream is a tributary of the Santa Ana River. A measurement was made July 13 by K. Sanborn. Measurement made over weir.

Discharge, 1.66 second-feet.

*Devil Canyon near Irvington Station, Cal.*—This stream is a tributary of the Santa Ana River. A measurement was made July 13 by K. Sanborn at the mouth of the canyon, 100 feet below head of M. L. & W. Co.'s ditch.

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Discharge, 1.26 second-feet.

*East Twin Creek near Arrowhead Springs, Cal.*—This stream is a tributary of the Santa Ana River. A measurement was made September 23 by W. B. Clapp at the mouth of the canyon. Measurement made over weir.

Discharge, 0.54 second-foot.

*Lytle Creek near Rialto, Cal.*—This stream is one of the principal tributaries of the Santa Ana River. A measurement was made June 16 by K. Sanborn at the head of Fontella Development Company's canal at the mouth of the canyon. Measurement made over weir.

Discharge, 23 second-feet.

*Mill Creek near Mentone, Cal.*—This stream is one of the principal tributaries of the Santa Ana River. The following measurements were made during 1905:

At road crossing between Mentone and Santa Ana Canyon, April 14: Width, 16 feet; area, 11.2 square feet; mean velocity, 4.11 feet per second; discharge, 46 second-feet. This is waste water and does not include water diverted by Crafton Zanja.

At head of Crafton Zanja, September 23: Width, 7.7 feet; area, 4.7 square feet; mean velocity, 4.33 feet per second; discharge, 20 second-feet.

*Morton Canyon Creek near Mentone, Cal.*—This stream is a small tributary of Santa Ana River. A measurement was made September 22 by W. B. Clapp at the mouth of the canyon, 500 feet above its junction with Santa Ana River.

Width, 0.8 foot; area, 0.096 square foot; mean velocity, 1.67 feet per second; discharge, 0.16 second-foot.

*Plunge Creek near East Highlands, Cal.*—This stream is a tributary of the Santa Ana River. The following measurements were made during 1905:

At road crossing Orange avenue between Redlands and Highlands, April 15: Width, 16 feet; area, 5.1 square feet; mean velocity, 1.94 feet per second; discharge, 9.9 second-feet.

At cement ditch at the mouth of the canyon, September 22: Width, 2 feet; area, 0.6 square foot; mean velocity, 1.67 foot per second; discharge, 1.0 second-foot.

*Redlands tunnel near Mentone, Cal.*—This is developed water from tunnel in the bed of the Santa Ana River at the mouth of the canyon. A measurement was made September 22 over weir at the mouth of the tunnel.

Discharge, 1.1 second-feet.

*Santa Ana River near Redlands, Cal.*—A measurement of this stream was made at the road crossing at Orange avenue between Redlands and Highlands April 14.

Width, 55 feet; area, 34 square feet; mean velocity, 2.35 feet per second; discharge, 76 second-feet.

*Santa Ana River near Rincon, Cal.*—The following measurements were made during 1905 at the Rincon wagon bridge, at the lower end of San Bernardino Valley, and the head of the lower Santa Ana Canyon. These measurements, with the addition of those of Chino Creek, show the total discharge of the Santa Ana River below all diversions in San Bernardino Valley, and show the amount of water which is used for irrigation in the vicinity of Orange, Santa Ana, Anaheim, and Fullerton, Cal., diversions being made below this point of measurement.

The gage is a 1 by 4 inch timber, graduated to feet and tenths and bolted to the first caisson from the south end of the Rincon wagon bridge. There is no bench mark.

February 24: Width, 40 feet; area, 68 square feet; mean velocity, 3.01 feet per second; gage height, 3.63 feet; discharge, 205 second-feet.

April 17: Width, 48 feet; area, 68 square feet; mean velocity, 2.53 feet per second; gage height, 3.60 feet; discharge, 172 second-feet.

May 16: Width, 45 feet; area, 50 square feet; mean velocity, 2.30 feet per second; gage height, 3.35 feet; discharge, 115 second-feet.

June 6: Width, 45 feet; area, 44 square feet; mean velocity, 1.98 feet per second; gage height, 3.32 feet; discharge, 87 second-feet.

July 29: Width, 48 feet; area, 34 square feet; mean velocity, 2.06 feet per second; gage height, 3.25 feet; discharge, 70 second-feet.

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September 21: Width, 46 feet; area, 39 square feet; mean velocity, 1.95 feet per second; gage height, 3.33 feet; discharge, 76 second-feet.

*Waterman Canyon Creek or West Twin Creek, near Arrowhead Springs, Cal.*—This stream is a tributary of Santa Ana River. A measurement was made July 13 by K. Sanborn at the bridge on the road to Waterman's ranch at the mouth of the canyon.

Discharge, 1.02 second-feet.

## SAN GABRIEL RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

The San Gabriel River rises in the Sierra Madre Mountains and, flowing in a southwesterly direction through the San Gabriel and Los Angeles valleys, discharges its waters into the Pacific Ocean near Long Beach, Cal. In the upper reaches of this basin there are numerous tributaries, which have their source in the higher elevations of the Sierra Madre Range. The topography in the upper reaches of this basin is rough and rugged, with deep and narrow canyons, while on the lower elevations the country is rolling, with large areas of valley land. The formation on the higher mountain elevation is of granite, with a light soil covering, with sparse timber growth. As one approaches the middle elevations the covering is brush, with scattering timber, while in the foothill country there is nothing but a growth of grass. The gaging station on this stream is located at a point where the stream leaves the higher mountains in the vicinity of Azusa. Below this point the river enters San Gabriel Valley, where the stream has a comparatively light grade, the bed being composed of bowlders, gravel, and sand, in which the water quickly disappears, except in times of flood discharge. The waters of this stream again appear on the surface at the lower end of San Gabriel Valley, at the discharge from the foothills, where an obstruction to the underground passage forces the water to the surface, on which it flows for a short distance and again disappears in the sands of the flat country below the foothills. The entire flow of this stream during the summer months is diverted at a point about 5 miles above the gaging station and is used for power purposes at the mouth of the canyon. From this point it is carried in ditches and used for irrigation in San Gabriel Valley. The water is again diverted where it appears on the surface at the lower end of this valley and is used for irrigation on the lower levels below this point. The mean precipitation in this basin varies from 15 to 30 inches and is principally in the form of rain. On small areas in the higher mountain elevations the precipitation is in the form of snow, which melts in the early spring months.

### SAN GABRIEL RIVER AND CANALS NEAR AZUSA, CAL.

Owing to the numerous diversions, it has been difficult to obtain accurate discharge measurements at Azusa, but during 1898 the San Gabriel Electric Company completed its system, and measurements are now obtained with greater ease and hence with greater accuracy. The headworks of this company are located about 6 miles above the mouth of the canyon. The water is carried around the left side by a series of tunnels and conduits, and a head of 400 feet is obtained where the electric power is generated. Weirs are placed on the conduit of the electric company and the water is measured at this point. The capacity of the conduit is 80 second-feet.

The cable and gage are located about 1 mile from Azusa. During the season of low water for a period of from six to eight months the canals above the station divert the entire flow and there is no running water at the station. The total flow of the river is obtained by adding the daily discharge for the river to the figures for the corresponding dates for the canals.

The channel is straight for 100 feet above and 500 feet below the cable and has a width of 280 feet at high water. At low stages there are two channels having different elevations, and accurate measurements are difficult to obtain. The bed of the stream is composed of cobblestones and bowlders, and the current is swift.

Discharge measurements are made by means of a cable and car. The gage is a vertical staff. During 1905 the gage was read by Don. D. Morgan.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 100, and 134 of the United States Geological Survey.

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*Discharge measurements of San Gabriel River and canals near Azusa, Cal., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | | |
|---|---|---|---|---|---|
| | | | River. | Canal. | Total. |
| | | *Feet.* | *Sec.-feet.* | *Sec.-feet.* | *Sec.-feet.* |
| February 10 | E. C. La Rue | 2.20 | 190 | 66 | 256 |
| February 17 | do | 3.50 | 560 | 66 | 626 |
| March 12 | R. S. Hawley | 9.30 | 11,055 | 72 | 11,127 |
| March 14 | W. B. Clapp | 5.30 | 2,030 | 70 | 2,100 |
| March 16 | R. S. Hawley | 5.80 | 3,225 | 80 | 3,305 |
| March 24 | do | 4.20 | 611 | 54 | 665 |
| March 31 | do | 3.80 | 400 | 80 | 480 |
| April 13 | do | 3.45 | 262 | 80 | 342 |
| April 19 | do | 3.30 | 190 | 80 | 270 |
| May 2 | do | 4.12 | 553 | 80 | 633 |
| May 9 | do | 3.50 | 288 | 80 | 368 |
| June 5 | do | 2.91 | 97 | 80 | 177 |
| June 23 | W. B. Clapp | 2.60 | 41 | 84 | 125 |
| July 5 | Hawley and Clapp | 2.28 | 17 | 85 | 102 |
| November 4 | W. B. Clapp | ..... | 00 | 30 | 30 |

*Daily gage height, in feet, of San Gabriel River near Azusa, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 2.1 | a 3.8 | 3.1 | 2.95 | 2.4 |
| 2 | 0 | 2.6 | 2.1 | a 3.75 | 3.7 | 2.95 | 2.35 |
| 3 | 0 | 5.5 | 2.1 | a 3.75 | 3.4 | 2.95 | 2.35 |
| 4 | 0 | a 4.75 | 2.1 | a 3.7 | 3.3 | 2.9 | 2.35 |
| 5 | 0 | 4.0 | 2.3 | a 3.7 | 3.2 | 2.9 | 2.25 |
| 6 | 0 | 3.0 | 2.3 | a 3.65 | 3.2 | 2.9 | 2.25 |
| 7 | 0 | 2.7 | 1.7 | a 3.65 | 3.2 | 2.85 | 2.2 |
| 8 | 0 | 2.5 | 1.7 | a 3.6 | 4.0 | 2.85 | 2.15 |
| 9 | 0 | 2.3 | 1.65 | a 3.6 | 3.6 | 2.85 | 2.15 |
| 10 | 0 | 2.2 | 1.65 | a 3.55 | 3.5 | 2.8 | 2.15 |
| 11 | 0 | 2.0 | 1.7 | a 3.55 | 3.4 | 2.8 | 2.55 |
| 12 | 0 | 1.9 | 9.3 | a 3.5 | 3.4 | 2.8 | 2.15 |
| 13 | 0 | 1.8 | a 7.3 | 3.5 | 3.3 | 2.8 | 2.15 |
| 14 | 0 | 1.8 | 5.3 | 3.45 | 3.3 | 2.8 | 2.1 |
| 15 | 0 | a 3.0 | 4.7 | a 3.4 | 3.3 | 2.75 | 2.1 |
| 16 | 0 | a 3.5 | 5.8 | a 3.4 | 3.3 | 2.7 | 2.05 |
| 17 | 0 | a 3.5 | 5.1 | a 3.4 | 3.3 | 2.7 | 2.0 |
| 18 | 0 | 3.1 | 4.8 | a 3.35 | 3.3 | 2.7 | 1.9 |
| 19 | 0 | 3.0 | 4.7 | 3.3 | 3.3 | 2.65 | 1.8 |
| 20 | 0 | 2.8 | 4.4 | 3.3 | 3.2 | 2.6 | 1.5 |
| 21 | 0 | 2.7 | 4.3 | 3.3 | 3.2 | 2.6 | (b) |
| 22 | 1.55 | 2.5 | 4.2 | 3.3 | 3.2 | 2.6 | ..... |
| 23 | 0 | 2.4 | 4.2 | 3.2 | 3.2 | 2.6 | ..... |
| 24 | 0 | 2.3 | 4.2 | 3.2 | 3.15 | 2.6 | ..... |
| 25 | 0 | 2.2 | 4.2 | 3.2 | 3.1 | 2.55 | ..... |
| 26 | 0 | 2.2 | a 4.2 | 3.2 | 3.1 | 2.55 | ..... |
| 27 | 0 | 2.2 | a 4.1 | 3.1 | 3.1 | 2.55 | ..... |
| 28 | 0 | 2.2 | a 4.0 | 3.1 | 3.1 | 2.5 | ..... |
| 29 | 0 | ..... | 4.0 | 3.1 | 3.1 | 2.45 | ..... |
| 30 | 0 | ..... | a 3.9 | 3.05 | 3.05 | 2.45 | ..... |
| 31 | 0 | ..... | 3.8 | ..... | 3.0 | ..... | ..... |

a Estimated.

b Dry from July 21 to December 31.

NOTE.—Gage washed out on March 12; replaced April 19. Gage heights taken with a level between March 12 and April 19.



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*Station rating table for San Gabriel River near Azusa, Cal., from February 2 to March 11, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.10 | 0 | 2.50 | 207 | 3.60 | 610 | 4.70 | 1,620 |
| 1.50 | 55 | 2.60 | 231 | 3.70 | 670 | 4.80 | 1,750 |
| 1.60 | 65 | 2.70 | 259 | 3.80 | 730 | 4.90 | 1,900 |
| 1.70 | 76 | 2.80 | 289 | 3.90 | 800 | 5.00 | 2,050 |
| 1.80 | 88 | 2.90 | 320 | 4.00 | 870 | 5.10 | 2,220 |
| 1.90 | 101 | 3.00 | 351 | 4.10 | 950 | 5.20 | 2,390 |
| 2.00 | 115 | 3.10 | 390 | 4.20 | 1,040 | 5.30 | 2,570 |
| 2.10 | 130 | 3.20 | 430 | 4.30 | 1,140 | 5.40 | 2,750 |
| 2.20 | 147 | 3.30 | 470 | 4.40 | 1,250 | 5.50 | 2,940 |
| 2.30 | 165 | 3.40 | 513 | 4.50 | 1,370 | | |
| 2.40 | 185 | 3.50 | 560 | 4.60 | 1,490 | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during first part of 1905; 1904 table applies from January 1 to February 1, inclusive.

*Station rating table for San Gabriel River near Azusa, Cal., from March 12 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.70 | 1 | 3.20 | 170 | 4.70 | 1,040 | 6.40 | 4,499 |
| 1.80 | 2.5 | 3.30 | 202 | 4.80 | 1,160 | 6.60 | 4,951 |
| 1.90 | 4.5 | 3.40 | 237 | 4.90 | 1,300 | 6.80 | 5,403 |
| 2.00 | 7 | 3.50 | 273 | 5.00 | 1,460 | 7.00 | 5,855 |
| 2.10 | 10 | 3.60 | 311 | 5.10 | 1,640 | 7.20 | 6,307 |
| 2.20 | 14 | 3.70 | 351 | 5.20 | 1,830 | 7.40 | 6,759 |
| 2.30 | 18 | 3.80 | 394 | 5.30 | 2,030 | 7.60 | 7,211 |
| 2.40 | 24 | 3.90 | 441 | 5.40 | 2,245 | 7.80 | 7,663 |
| 2.50 | 32 | 4.00 | 492 | 5.50 | 2,470 | 8.00 | 8,115 |
| 2.60 | 42 | 4.10 | 550 | 5.60 | 2,695 | 8.20 | 8,567 |
| 2.70 | 55 | 4.20 | 616 | 5.70 | 2,920 | 8.40 | 9,019 |
| 2.80 | 71 | 4.30 | 687 | 5.80 | 3,145 | 8.60 | 9,471 |
| 2.90 | 90 | 4.40 | 762 | 5.90 | 3,370 | 8.80 | 9,923 |
| 3.00 | 113 | 4.50 | 841 | 6.00 | 3,595 | 9.00 | 10,375 |
| 3.10 | 140 | 4.60 | 935 | 6.20 | 4,047 | 9.20 | 10,828 |

NOTE.—The above table is applicable only for open-channel conditions. It is based on 11 discharge measurements made during 1905.

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*Daily discharge, in second-feet, of San Gabriel canals near Azusa, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30 | 34 | 67 | 80 | 80 | 80 | 85 | 55 | 34 | 30 | 29 | 50 |
| 2 | 23 | 67 | 67 | 80 | 80 | 80 | 85 | 54 | 33 | 29 | 29 | 47 |
| 3 | 21 | 70 | 67 | 80 | 80 | 80 | 86 | 54 | 32 | 28 | 29 | 45 |
| 4 | 20 | 78 | 67 | 80 | 80 | 80 | 85 | 53 | 33 | 28 | 29 | 44 |
| 5 | 19.5 | 68 | 0 | 80 | 80 | 80 | 85 | 52 | 34 | 28 | 29 | 44 |
| 6 | 19 | 78 | 67 | 80 | 80 | 80 | 86 | 50 | 35 | 28 | 32 | 42 |
| 7 | 18.5 | 69 | 72 | 80 | 80 | 80 | 86 | 47 | 34 | 28 | 44 | 42 |
| 8 | 18.5 | 86 | 72 | 80 | 48 | 80 | 85 | 46 | 33 | 28 | 95 | 41 |
| 9 | 41 | 74 | 72 | 80 | 80 | 80 | 85 | 45 | 32 | 27 | 53 | 39 |
| 10 | 59 | 66 | 72 | 80 | 80 | 80 | 85 | 45 | 32 | 27 | 42 | 37 |
| 11 | 40 | 66 | 72 | 80 | 80 | 73 | 71 | 46 | 32 | 27 | 38 | 37 |
| 12 | 35 | 66 | 72 | 80 | 80 | 73 | 74 | 44 | 32 | 27 | 36 | 37 |
| 13 | 31 | 66 | 0 | 80 | 80 | 76 | 75 | 44 | 32 | 28 | 36 | 38 |
| 14 | 29 | 66 | 70 | 80 | 80 | 76 | 74 | 43 | 31 | 29 | 34 | 39 |
| 15 | 27 | 66 | 79 | 80 | 80 | 0 | 74 | 43 | 31 | 29 | 34 | 39 |
| 16 | 30 | 67 | 80 | 80 | 80 | 78 | 74 | 42 | 30 | 29 | 45 | 39 |
| 17 | 30 | 66 | 80 | 80 | 80 | 78 | 74 | 41 | 31 | 30 | 53 | 39 |
| 18 | 28 | 68 | 80 | 80 | 80 | 78 | 74 | 40 | 31 | 30 | 43 | 39 |
| 19 | 28 | 60 | 79 | 80 | 80 | 78 | 73 | 41 | 30 | 30 | 40 | 38 |
| 20 | 27 | 68 | 80 | 80 | 80 | 78 | 73 | 41 | 29 | 29 | 42 | 46 |
| 21 | 55 | 68 | 80 | 80 | 80 | 78 | 70 | 40 | 29 | 29 | 41 | 42 |
| 22 | 67 | 68 | 78 | 80 | 80 | 88 | 69 | 40 | 28 | 31 | 39 | 39 |
| 23 | 67 | 68 | 57 | 80 | 80 | 84 | 68 | 39 | 30 | 32 | 38 | 38 |
| 24 | 57 | 67 | 54 | 80 | 80 | 84 | 67 | 38 | 30 | 31 | 37 | 37 |
| 25 | 46 | 68 | 69 | 80 | 80 | 84 | 64 | 38 | 30 | 30 | 37 | 38 |
| 26 | 41 | 67 | 80 | 80 | 80 | 84 | 62 | 36 | 29 | 29 | 37 | 38 |
| 27 | 40 | 67 | 80 | 80 | 80 | 84 | 64 | 36 | 30 | 29 | 97 | 38 |
| 28 | 38 | 67 | 80 | 80 | 80 | 84 | 62 | 35 | 31 | 28 | 87 | 38 |
| 29 | 37 | ..... | 80 | 80 | 80 | 84 | 60 | 34 | 32 | 28 | 62 | 37 |
| 30 | 36 | ..... | 80 | 80 | 80 | 84 | 68 | 33 | 31 | 29 | 53 | 37 |
| 31 | 34 | ..... | 80 | ..... | 80 | ..... | 56 | 33 | ..... | 28 | ..... | 38 |

*Estimated monthly discharge of San Gabriel River[a] near Azusa, Cal., for 1905.*

[Drainage area, 222 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 108 | 18.5 | 36.6 | 2,251 | 0.165 | 0.190 |
| February | 3,010 | 34 | 466 | 25,880 | 2.10 | 2.19 |
| March | 11,130 | 142 | 1,222 | 75,140 | 5.50 | 6.34 |
| April | 474 | 206 | 329 | 19,580 | 1.48 | 1.65 |
| May | 540 | 193 | 278 | 17,090 | 1.25 | 1.44 |
| June | 182 | 63 | 139 | 8,271 | .626 | .698 |
| July | 109 | 56 | 83.0 | 5,103 | .374 | .431 |
| August | 55 | 33 | 42.8 | 2,631 | .193 | .222 |
| September | 35 | 28 | 31.4 | 1,869 | .141 | .157 |
| October | 32 | 27 | 28.8 | 1,771 | .130 | .150 |
| November | 97 | 29 | 44.7 | 2,660 | .201 | .224 |
| December | 50 | 37 | 40.1 | 2,466 | .181 | .209 |
| The year | 11,130 | 18.5 | 2,284 | 164,700 | 1.03 | 13.90 |

[a] Includes water in canal.

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### MISCELLANEOUS MEASUREMENTS IN SAN GABRIEL RIVER DRAINAGE BASIN.

The following is a list of miscellaneous discharge measurements made in the San Gabriel River drainage basin during 1905:

*Baldwin ditch near El Monte, Cal.*—This ditch diverts water from the Rio Hondo River and is used for irrigation of land in the vicinity of the Old Mission. A measurement was made October 6 by W. B. Clapp at Old Mission Bridge, 4 miles below El Monte, Cal.

Width, 1.2 feet; area, 1.4 square feet; mean velocity, 2.14 feet per second; discharge, 3.0 second-feet.

*Cate ditch near El Monte, Cal.*—This ditch diverts water from the San Gabriel River and is used for the irrigation of land in the vicinity of Rivera, Cal. A measurement was made October 6 by W. B. Clapp in flume at road crossing near county road between El Monte and Whittier and about 5 miles below El Monte.

Width, 4 feet; area, 7.7 square feet; mean velocity, 1.45 feet per second; discharge, 11.2 second-feet.

*Ranchito or Standerford ditch near El Monte, Cal.*—This ditch diverts water from the San Gabriel River and is used for the irrigation of land in the vicinity of Rivera and Downey, Cal. A measurement was made October 6 by W. B. Clapp 25 feet below head-gate and about 5 miles below El Monte, Cal.

Width, 11.8 feet; area, 11 square feet; mean velocity, 1.42 feet per second; discharge, 15.6 second-feet.

*Los Nietos or Banta ditch.*—This ditch diverts water from the San Gabriel River and is used for the irrigation of land in the vicinity of Los Nietos, Cal. A measurement was made October 6 by W. B. Clapp 100 feet below head-gate of Ranchito ditch.

Width, 18 feet; area, 14.8 square feet; mean velocity, 1.14 feet per second; discharge, 16.8 second-feet.

*Rio Hondo near El Monte, Cal.*—This stream constitutes one branch of the San Gabriel River. A measurement was made October 6 by W. B. Clapp at Old Mission Bridge, 4 miles below El Monte and below the diversion of the Baldwin ditch.

Width, 13 feet; area, 12 square feet; mean velocity, 1.75 feet per second; discharge, 21 second-feet.

*Rincon ditch near El Monte, Cal.*—This ditch diverts water from the San Gabriel River 2 miles below Southern Pacific Railroad bridge and is used for irrigation of land in the vicinity of Rincon, Cal. A measurement was made October 6 by W. B. Clapp at road crossing, one-half mile east of the Durfee ranch.

Width, 6 feet; area, 3.2 square feet; mean velocity, 1.06 feet per second; discharge, 3.4 second-feet.

*Sheep Creek ditch near El Monte, Cal.*—This ditch diverts water from Sheep Creek, a tributary of San Gabriel River. A measurement was made October 6 by W. B. Clapp in flume at road crossing, 1 mile east of Durfee ranch.

Width, 3 feet; area, 2.1 square feet; mean velocity, 2.19 feet per second; discharge, 4.6 second-feet.

*Santa Anita Creek near Sierra Madre, Cal.*—This stream is a tributary of the San Gabriel River. A measurement was made October 23 by W. B. Clapp at the mouth of the canyon above Baldwin diversion.

Width, 3 feet; area, 1.0 square foot; mean velocity, 1.50 feet per second; discharge, 1.5 second-feet.

*San Gabriel River near El Monte, Cal.*—A measurement was made of this stream on April 13 by R. S. Hawley at wagon bridge, 2 miles east of El Monte, Cal.

Width, 56 feet; area, 20 square feet; mean velocity, 2.35 feet per second; discharge, 47 second-feet.

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## LOS ANGELES RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

The Los Angeles River is formed by the Tujunga, Pacoima, and other small creeks which have their source in the Sierra Madre Range of mountains to the northeast of the city of Los Angeles. These streams leave the mountains at a point about 25 miles above the city and enter the comparatively flat country of San Fernando Valley, where, except in times of excessive flood, the waters disappear in the sand and gravel washes of the valley. These waters again make their appearance at the lower end of this valley, where a secondary range of hills, extending from east to west, forces the waters to the surface in what is known as Los Angeles River. Below this point the river discharges through the flat country of Los Angeles Valley, finally entering the Pacific Ocean near the town of Long Beach, Cal. During the summer months the entire flow of Los Angeles River is diverted at a point about 5 miles above Los Angeles for the supply of the city, and only a small amount of water passes this point except during flood discharge of the river. The topography is rough in the upper reaches of this drainage basin, the streams discharging in deep, narrow canyons. In this portion of the drainage basin the formation is of granite, with good soil covering and light timber and heavy brush growth. There is a considerable area of foothill country within this basin, lying between the base of the Sierra Madre Range and Los Angeles Valley, which has a light covering of brush and grass. The soil of San Fernando Valley consists principally of river wash, coarse sand, and gravel, except along the base of the mountains and foothills, where the soil is of good depth and is under a high state of cultivation. The soil of Los Angeles Valley, below the city of Los Angeles, consists of a light sandy loam and is under a high state of cultivation. The mean precipitation throughout this basin is from 15 to 30 inches and falls in the form of rain, except on small areas on the higher mountain elevations.

### MISCELLANEOUS MEASUREMENTS IN LOS ANGELES RIVER DRAINAGE BASIN.

The following is a list of miscellaneous discharge measurements made in Los Angeles River drainage basin during 1905:

*Arroyo Seco near Pasadena, Cal.*—This stream is a tributary of Los Angeles River. The following measurements were made on this stream during 1905 by W. B. Clapp:

At mouth of canyon, 5 miles above Pasadena, Cal., April 11: Width, 13.5 feet; area, 8.1 square feet; mean velocity, 2.11 feet per second; discharge, 17.1 second-feet.

At Devils Gate, 3 miles above Pasadena, Cal., April 11: Width, 8 feet; area, 8.7 square feet; mean velocity, 1.44 feet per second; discharge, 12.5 second-feet.

At point 1,000 feet above submerged dam of Pasadena Land and Water Company, at Pasadena, Cal., April 11: Width, 8 feet; area, 2 square feet; mean velocity, 1.30 feet per second; discharge, 2.6 second-feet.

At sycamore grove, near Morgan's south line, Los Angeles, Cal., by J. B. Lippincott, October 27: Width, 1.1 feet; area, 0.16 square foot; mean velocity, 0.64 foot per second; discharge, 0.10 second-foot.

At sycamore grove, 600 feet above Morgan's south line, October 27: Width, 1.2 feet; area, 0.20 square foot; mean velocity, 1.14 feet per second; discharge, 0.23 second-foot.

*Big Tejunga Creek near Sunland, Cal.*—This stream is a tributary of the Los Angeles River. The following measurements were made during 1905 by R. S. Hawley:

At mouth of canyon, 1 mile above Sunland, Cal., April 12: Width, 25 feet; area, 13.7 square feet; mean velocity, 4.45 feet per second; discharge, 61 second-feet.

At Southern Pacific Company's railroad crossing near Pacoima, Cal., April 12: Width, 25 feet; area, 10.3 square feet; mean velocity, 2.82 feet per second; discharge, 29 second-feet.

Two miles below Southern Pacific Railroad bridge at Pacoima, Cal., April 12: No discharge.

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*Little Tejunga Creek near Sunland, Cal.*—This stream is a tributary of Los Angeles River and discharges into Big Tejunga Creek below Sunland. A measurement was made April 11 by R. S. Hawley at mouth of canyon two-thirds of a mile above the junction with Big Tejunga Creek.

Width, 6 feet; area, 1.6 square feet; mean velocity, 2.06 feet per second; discharge, 3.3 second-feet.

*Pacoima Creek near Fernando, Cal.*—This stream is a tributary of Los Angeles River. The following measurements were made during 1905 by R. S. Hawley:

At mouth of canyon, 5 miles above Fernando, Cal., April 12: Width, 20 feet; area, 7.3 square feet; mean velocity, 4.11 feet per second; discharge, 30 second-feet.

At Southern Pacific Railroad bridge, 1 mile east of Fernando, Cal., April 12: Width, 10 feet; area, 6.2 square feet; mean velocity, 2.84 feet per second; discharge, 17.6 second-feet.

Three miles below Southern Pacific Railroad bridge, near Fernando, Cal., April 12: No discharge.

### MISCELLANEOUS MEASUREMENTS ON LOS ANGELES RIVER.

The following measurements were made on Los Angeles River at Los Angeles, Cal., during 1905:

*At Fourth Street Bridge.*—March 13: Width, 120 feet; area, 446 square feet; mean velocity, 10.15 feet per second; discharge, 4,525 second-feet.

*At Huron street.*—April 12: Width, 38 feet; area, 20 square feet; mean velocity, 2.15 feet per second; discharge, 43 second-feet.

*At Ninth Street Bridge.*—April 12: Width, 13 feet; area, 5.8 square feet; mean velocity, 2.19 feet per second; discharge, 12.7 second-feet.

During the summer of 1905 measurements were made to determine the amount of water diverted by the city of Los Angeles for domestic supply and also to determine the amount of water which passes the city's diversion point. The amount of water diverted for the city's supply is shown in measurements made in the 44-inch conduit and the main supply conduit. The amount of water discharging in the river below these points of diversion is shown by measurements made at Huron street. The following measurements were made during 1905 at these points:

*Measurements on Los Angeles River in Los Angeles.*

| Date. | 44-inch conduit discharge. | Main supply conduit discharge. | Huron street. | | | |
|---|---|---|---|---|---|---|
| | | | Width. | Area. | Mean velocity. | Discharge. |
| | *Sec.-ft.* | *Sec.-ft.* | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Sec.-ft.* |
| May 15 | 42 | 11 | 24 | 7.2 | 1.47 | 10.6 |
| June 22 | 38 | 9.9 | 16 | 3.2 | 1.03 | 3.3 |
| July 28 | 37 | 8.4 | 6 | 2.2 | 1.77 | 4.6 |
| September 19 | 35.3 | 8.7 | 6 | 2.2 | 1.55 | 3.4 |

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## MALIBU CREEK DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Malibu Creek rises in the Santa Monica Mountains and enters the Pacific Ocean about 15 miles above the town of Santa Monica. This stream is formed by Triunfo and Las Virgenes creeks, which drain the northern portion of the Santa Monica Range and the lower foothill country to the north. The formation throughout this basin is shale, sandstone, and conglomerate, with good soil covering. There is a sparse growth of timber on the higher elevations, but a greater portion of this area has a covering of brush and grass used extensively for pasturage, with limited areas of cultivated land for the raising of grain. A reservoir has been constructed on the upper reaches of the Triunfo Creek and the waters are used for irrigation within the basin during the summer months. This reservoir covers an area of about 300 acres when filled.

The mean precipitation in this basin amounts to about 25 inches and falls wholly in the form of rain.

### MALIBU CREEK NEAR CALABASAS, CAL.

This station was established November 29, 1901, by S. G. Bennett. It is located at Chapman's ranch, 40 miles from Los Angeles, by wagon road, and 8 miles southwest of Calabasas, about one-fourth mile below the mouth of Las Virgenes Creek.

The channel section is poor and subject to change during high water, but is at the only point where an observer could be secured. The excessive cost of visiting the station has made it impossible to obtain as many meter measurements as desired, but the observer is instructed to take float velocities at various gage heights, and these data, with cross sections and slope, are used in addition to meter measurements for computing discharges for use in constructing rating curves and tables. The estimated discharge is a rough approximation only.

The channel is straight for about 600 feet above the station and curved for about 300 feet below. The current is swift. Both banks are high. The right bank is rocky, and the bed of the stream is composed of rock and gravel.

The initial point for soundings is on the right bank. The gage rod is a vertical staff fastened to an alder tree on the right bank. During 1905 the gage was read by J. G. Chapman. The bench mark is a cross on a small projection on a rock bluff about 10 feet southwest of the gage rod; elevation, 5.43 feet above the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 100 and 134 of the United States Geological Survey.

*Discharge measurements of Malibu Creek near Calabasas, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| April 20 | R. S. Hawley | 9 | 6.2 | 1.5 | 0.9 | 9.3 |
| May 12 | do | 9 | 6.3 | 1.35 | .82 | 8.5 |

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*Daily gage height, in feet, of Malibu Creek near Calabasas, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.2 | 1.2 | 1.1 | 1.5 | 0.8 | 0.6 | 0.5 | 0.5 | 0.5 | 0.4 | 0.45 | 0.5 |
| 2 | 1.2 | 1.3 | 1.1 | 1.25 | .8 | .6 | .5 | .5 | .5 | .4 | .45 | .5 |
| 3 | 1.2 | 1.6 | 1.1 | 1.2 | .8 | .6 | .5 | .5 | .5 | .4 | .45 | .5 |
| 4 | 1.2 | 2.85 | 1.1 | 1.2 | .8 | .6 | .5 | .5 | .5 | .4 | .45 | .5 |
| 5 | 1.2 | 1.85 | 1.1 | 1.2 | .8 | .6 | .5 | .5 | .5 | .4 | .55 | .5 |
| 6 | 1.2 | 2.1 | 1.1 | 1.25 | .8 | .6 | .5 | .5 | .5 | .4 | .55 | .5 |
| 7 | 1.2 | 1.3 | 1.1 | 1.25 | 1.3 | .6 | .5 | .5 | .5 | .4 | .55 | .5 |
| 8 | 1.2 | 1.2 | 1.1 | 1.25 | .9 | .6 | .5 | .5 | .5 | .4 | .55 | .5 |
| 9 | 1.2 | 1.15 | 1.1 | 1.2 | .9 | .6 | .6 | .5 | .5 | .4 | .55 | .5 |
| 10 | 1.2 | 1.15 | 1.1 | 1.2 | .9 | .6 | .6 | .5 | .5 | .4 | .55 | .6 |
| 11 | 1.2 | 1.15 | 1.0 | 1.2 | .9 | .6 | .6 | .5 | .45 | .4 | .55 | .6 |
| 12 | 1.2 | 1.15 | 7.6 | 1.1 | .9 | .6 | .6 | .5 | .45 | .4 | .6 | .6 |
| 13 | 1.2 | 1.15 | 4.2 | 1.25 | .9 | .6 | .6 | .5 | .45 | .4 | .6 | .6 |
| 14 | 1.2 | 1.1 | 3.25 | 1.0 | .7 | .6 | .6 | .5 | .45 | .4 | .6 | .6 |
| 15 | 1.2 | 1.1 | 3.25 | 1.0 | .7 | .6 | .6 | .5 | .45 | .4 | .6 | .6 |
| 16 | 1.2 | 1.8 | 4.75 | 1.0 | .7 | .6 | .6 | .5 | .45 | .4 | .6 | .6 |
| 17 | 1.2 | 1.65 | 3.55 | 1.0 | .7 | .6 | .6 | .5 | .45 | .4 | .6 | .6 |
| 18 | 1.2 | 1.55 | 2.8 | .9 | .7 | .6 | .6 | .5 | .4 | .4 | .6 | .6 |
| 19 | 1.22 | 1.4 | 2.5 | .9 | .7 | .6 | .6 | .5 | .4 | .4 | .6. | .6 |
| 20 | 1.25 | 1.3 | 2.4 | .9 | .7 | .6 | .6 | .5 | .4 | .4 | .6 | .6 |
| 21 | 1.3 | 1.2 | 2.4 | .9 | .7 | .6 | .6 | .5 | .4 | .4 | .6 | .6 |
| 22 | 1.24 | 1.2 | 2.3 | .9 | .7 | .6 | .6 | .5 | .4 | .4 | .6 | .6 |
| 23 | 1.2 | 1.15 | 2.2 | .9 | .7 | .6 | .5 | .5 | .45 | .4 | .6 | .6 |
| 24 | 1.2 | 1.1 | 2.2 | .9 | .7 | .6 | .5 | .5 | .45 | .4 | .6 | .6 |
| 25 | 1.2 | 1.1 | 1.0 | .9 | .7 | .5 | .5 | .5 | .45 | .4 | .6 | .6 |
| 26 | 1.2 | 1.1 | 1.6 | .9 | .7 | .5 | .5 | .5 | .45 | .4 | .5 | .6 |
| 27 | 1.2 | 1.1 | 1.45 | .9 | .7 | .5 | .5 | .5 | .45 | .4 | .5 | .6 |
| 28 | 1.2 | 1.1 | 1.55 | .8 | .6 | .5 | .5 | .5 | .45 | .4 | .5 | .6 |
| 29 | 1.2 | ..... | 1.7 | .8 | .6 | .5 | .5 | .5 | .45 | .45 | .5 | .6 |
| 30 | 1.2 | ..... | 1.7 | .8 | .6 | .5 | .5 | .5 | .45 | .45 | .5 | .6 |
| 31 | 1.2 | ..... | 1.55 | ..... | .6 | ..... | .5 | .5 | ..... | .45 | ..... | .6 |

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*Estimated monthly discharge of Malibu Creek near Calabasas, Cal., for 1905.*

[Drainage area, 97 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 10 | 5 | 5.4 | 332 | 0.056 | 0.065 |
| February | 560 | 2 | 36.1 | 2,005 | .372 | .387 |
| March | 6,800 | 1 | 484. | 29,760 | 4.99 | 5.75 |
| April | 41 | 8 | 14.4 | 857 | .148 | .165 |
| May | 24 | 4 | 7.3 | 449 | .075 | .086 |
| June | 4 | 3 | 3.8 | 226 | .039 | .044 |
| July | 3 | 3 | 3.0 | 184 | .031 | .036 |
| August | 3 | 3 | 3.0 | 184 | .031 | .036 |
| September | 3 | 1 | 2.1 | 125 | .022 | .024 |
| October | 2 | 1 | 1.1 | 68 | .011 | .013 |
| November | 4 | 2 | 3.6 | 214 | .037 | .041 |
| December | 4 | 3 | 3.7 | 228 | .038 | .044 |
| The year | 6,800 | 1 | 47.3 | 34,630 | .488 | 6.69 |

NOTE.—The estimated monthly discharge is only an approximation.

### TRIUNFO CREEK NEAR CALABASAS, CAL.

This station is located 8 miles southwest of Calabasas, Cal., about one-half mile above the mouth of Las Virgenes Creek.

The channel section is poor and subject to change during high water, but is at the only point where an observer could be secured. The excessive cost of visiting the station has made it impossible to obtain as many meter measurements as desired, but the observer is instructed to take float velocities during floods at various gage heights, and these data, with cross sections and grade of stream, are used in addition to meter measurements for computing discharges for use in constructing rating curves and tables. The estimated discharge from this stream is a rough approximation only.

The channel is straight for about 400 feet above and 800 feet below the station, and the water is swift. Both banks are high and rocky. The bed of the stream is composed of gravel and sand and is shifting.

The initial point for soundings is on the right bank. The gage rod is a vertical staff bolted to rock cliff on right bank. During 1905 the gage was read by J. G. Chapman. The bench mark is a cross on a point of rock 3.5 feet above the bed of the creek on the right bank; elevation, 4.53 feet above the datum of the gage.

Information in regard to this section is contained in Water-Supply Papers Nos. 100 and 134 of the United States Geological Survey.

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*Discharge measurements of Triunfo Creek near Calabasas, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| April 20 | R. S. Hawley | 15 | 7.1 | 1.13 | 1.60 | 8.0 |
| May 12 | do | 17 | 6.3 | 1.13 | 1.44 | 7.1 |

*Daily gage height, in feet, of Triunfo Creek near Calabasas, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. |
|---|---|---|---|---|---|---|---|
| 1 | ..... | 0.00 | 0.5 | 1.3 | ..... | 1.3 | 1.0 |
| 2 | ..... | .75 | .5 | 1.5 | ..... | 1.3 | 1.1 |
| 3 | ..... | .9 | .5 | 1.5 | ..... | 1.3 | 1.1 |
| 4 | ..... | 2.15 | .5 | 1.5 | ..... | 1.3 | 1.1 |
| 5 | ..... | 1.65 | .5 | 1.5 | ..... | 1.3 | 1.1 |
| 6 | ..... | 2.2 | .5 | 1.5 | ..... | 1.3 | 1.1 |
| 7 | ..... | 1.65 | .5 | 1.6 | 1.4 | 1.3 | 1.1 |
| 8 | ..... | 1.0 | .5 | 1.6 | .8 | 1.3 | 1.1 |
| 9 | ..... | .9 | .5 | 1.6 | .4 | 1.3 | 1.2 |
| 10 | ..... | .7 | .45 | 1.5 | ..... | 1.3 | 1.2 |
| 11 | ..... | .55 | .45 | 1.55 | ..... | 1.25 | 1.2 |
| 12 | ..... | .5 | 6.0 | 1.5 | ..... | 1.25 | 1.2 |
| 13 | ..... | .5 | 2.55 | 1.5 | ..... | 1.25 | 1.2 |
| 14 | ..... | .3 | 2.15 | 1.5 | 1.2 | 1.25 | 1.2 |
| 15 | ..... | .3 | 2.05 | 1.5 | 1.2 | 1.25 | 1.2 |
| 16 | ..... | 1.65 | 3.3 | 1.5 | 1.2 | 1.25 | 1.2 |
| 17 | ..... | 1.45 | 3.1 | 1.5 | 1.2 | 1.25 | 1.2 |
| 18 | ..... | 1.3 | 2.6 | 1.5 | 1.2 | 1.2 | 1.2 |
| 19 | ..... | 1.2 | 2.25 | 1.4 | 1.2 | 1.2 | 1.2 |
| 20 | ..... | 1.1 | 1.2 | 1.4 | 1.2 | 1.2 | 1.2 |
| 21 | ..... | .9 | 1.2 | 1.4 | 1.2 | 1.2 | 1.2 |
| 22 | ..... | .85 | 1.2 | 1.4 | 1.2 | 1.2 | 1.2 |
| 23 | ..... | .8 | 1.1 | ..... | 1.2 | 1.2 | 1.1 |
| 24 | ..... | .8 | 2.2 | ..... | 1.2 | 1.2 | 1.1 |
| 25 | ..... | .7 | 1.6 | ..... | 1.2 | 1.0 | 1.1 |
| 26 | ..... | .7 | 1.4 | ..... | 1.3 | 1.0 | 1.1 |
| 27 | ..... | .7 | 1.4 | ..... | 1.3 | 1.0 | 1.1 |
| 28 | ..... | .6 | 1.3 | ..... | 1.3 | 1.0 | 1.1 |
| 29 | ..... | ..... | 1.4 | ..... | 1.3 | 1.0 | 1.1 |
| 30 | ..... | ..... | 1.4 | ..... | 1.3 | 1.0 | 1.0 |
| 31 | ..... | ..... | 1.4 | ..... | 1.3 | ..... | 0.0 |

NOTE.—Creek dry Jan 2 to Feb. 1, Apr. 23 to May 6, May 10–13, Aug. 1 to Dec. 31.

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*Estimated monthly discharge of Triunfo Creek near Calabasas, Cal., for 1905.*

[Drainage area, 72 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 0 | 0 | 0.0 | 0 | 0.0 | 0.0 |
| February | 410 | 0 | 26.2 | 1,455 | .364 | .379 |
| March | 5,000 | 1 | 353.0 | 21,700 | 4.90 | 5.65 |
| April | 40 | 0 | 11.2 | 666 | .156 | .174 |
| May | 6 | 0 | 1.0 | 61 | .014 | .016 |
| June | 2 | 1 | 1.3 | 77 | .018 | .020 |
| July | 1 | 0 | .97 | 60 | .013 | .015 |
| August | 0 | 0 | .0 | 0 | .0 | .0 |
| September | 0 | 0 | .0 | 0 | .0 | .0 |
| October | 0 | 0 | .0 | 0 | .0 | .0 |
| November | 0 | 0 | .0 | 0 | .0 | .0 |
| December | 0 | 0 | .0 | 0 | .0 | .0 |
| The year | 5,000 | 0 | 32.8 | 24,020 | .455 | 6.25 |

NOTE.—The estimated monthly discharge is only an approximation.

## SANTA CLARA RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

The Santa Clara River rises in the Coast Range in the northwestern part of Los Angeles County and flows in a westerly direction, discharging its waters into the Pacific Ocean near Ventura, Cal. It has numerous tributaries from the north, all of which are torrential in their character, having a heavy discharge during the winter months. This stream has a comparatively flat grade, flowing over a sandy and gravelly bed, into which it sinks during a greater portion of the year. At numerous points along its course the water rises to the surface during the summer and flows for a short distance, again disappearing in the sand. At points where the waters make their appearance on the surface numerous diversions are made for irrigation along the valley, where the soil is deep and is under the highest state of cultivation, this being especially the case on the lower reaches of the river below the town of Santa Paula. The principal tributaries of this stream are Piru Creek, Sespe Creek, and Santa Paula Creek, all of which produce a very heavy flood discharge of short duration during the rainy season, but during the summer months have a light discharge. On the upper reaches of the principal tributaries of this stream the topography is rough and broken, the streams discharging through deep canyons. This is especially noticeable on the Sespe Creek. On the upper reaches of the main stream the country is rolling and has a sparse covering of timber with a considerable growth of brush and grass, and is used extensively for pasturage. The formation is of shale, sandstone, and conglomerate throughout the entire basin. The precipitation is extremely light in the upper reaches of this basin, but increases on the lower reaches nearer the Pacific Ocean and falls in the form of rain.

### MISCELLANEOUS MEASUREMENTS IN SANTA CLARA RIVER DRAINAGE BASIN.

The following is a list of miscellaneous discharge measurements made in the Santa Clara River drainage basin during 1905:

*Camulos ditch near Camulos, Cal.*—This ditch diverts water from the Santa Clara River 1 mile above Camulos, Cal. The water is used for the irrigation of land at Camulos. A measurement was made October 19 by W. B. Clapp in a flume about 1,000 feet below the head of the canal.

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Width, 3.5 feet; area, 3.5 square feet; mean velocity, 2.17 feet per second; discharge, 7.6 second-feet.

*Farmers' canal near Santa Paula, Cal.*—This canal diverts water from the Santa Clara River at a point 1 mile above Santa Paula, Cal. The water is used for irrigation of land between Santa Paula and Saticoy, Cal. A measurement was made October 21 by W. B. Clapp in flume 200 feet below where canal crosses Santa Clara River, about 1 mile above the town of Santa Paula, Cal.

Width, 4 feet; area, 4.8 square feet; mean velocity, 1.50 feet per second; discharge, 7.2 second-feet.

*Grees ditch near Santa Paula, Cal.*—This ditch diverts water from the Santa Clara River about 1 mile above the town of Santa Paula, Cal. The water is used for the irrigation of land between Santa Paula and Saticoy. A measurement was made on October 21 by W. B. Clapp at a point 200 feet below head of ditch and about 1 mile above the town of Santa Paula, Cal.

Width, 8 feet; area, 6.6 square feet; mean velocity, 1.39 feet per second; discharge, 9.2 second-feet.

*Piru Land and Water Company's upper diversion near Esperanza, Cal.*—This water is diverted from Piru Creek for domestic and irrigation purposes in the town of Piru, Cal. A measurement was made October 20 by W. B. Clapp at point of diversion at head of pipe line, 1 mile above the town of Esperanza, Cal.

Width, 5 feet; area, 1.5 square feet; mean velocity, 0.93 foot per second; discharge, 1.4 second-feet.

*Piru Creek near Esperanza, Cal.*—This stream is a tributary of the Santa Clara River. A measurement was made October 20 by W. B. Clapp at point 1 mile above Esperanza, Cal., and below the upper diversion of the Piru Land and Water Company.

Width, 8 feet; area, 2.4 square feet; mean velocity, 1.42 feet per second; discharge, 3.4 second-feet. For total flow of Piru Creek at this point add upper diversion of Piru Land and Water Company.

*Piru Creek near Piru City, Cal.*—A measurement was made October 20 by W. B. Clapp 1 mile above Piru City and above lower diversion of Piru Land and Water Company.

Width, 8 feet; area, 2.8 square feet; mean velocity, 1.90 feet per second; discharge, 5.3 second-feet. This measurement shows total flow of Piru Creek at this point and includes the discharge of Piru Creek 1 mile above Esperanza, Cal. The increase is caused by seepage water along the creek.

*Sespe Land and Water Company's canal near Sespe, Cal.*—This canal diverts water from Sespe Creek and is used for irrigation of land in the vicinity of Sespe. A measurement was made October 20 by W. B. Clapp one-half mile below head of canal.

Width, 5.2 feet; area, 4.5 square feet; mean velocity, 1.47 feet per second; discharge, 6.6 second-feet.

*Sespe Creek near Sespe, Cal.*—This creek is a tributary of the Santa Clara River. A measurement was made October 20 by W. B. Clapp one-half mile below heading of Sespe Land and Water Company's canal.

Width, 4 feet; area, 2.9 square feet; mean velocity, 1.66 feet per second; discharge, 4.8 second-feet. For total flow of Sespe Creek add discharge of Sespe Land and Water Company's canal as shown by measurement made on this date.

*San Francisquito Creek near Saugus, Cal.*—This creek is a tributary of the Santa Clara River. A measurement was made October 19 by W. B. Clapp at road crossing near Newhall ranch, 3½ miles below Saugus, Cal., and 500 feet above junction with Santa Clara River

Width, 5 feet; area, 2.8 square feet; mean velocity, 0.46 foot per second; discharge, 1.3 second-feet.

*Santa Paula Creek near Santa Paula, Cal.*—This stream is a tributary of the Santa Clara River. A measurement was made October 21 by W. B. Clapp 3 miles above Santa Paula and above diversion of the Santa Paula Land and Water Company.

Width, 11 feet; area, 5.6 square feet; mean velocity, 0.88 foot per second; discharge, 4.9 second-feet. This measurement shows total discharge of Santa Paula Creek on this date.

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*Santa Clara River near Saugus, Cal.*—A measurement was made October 19 by W. B. Clapp at road crossing near Newhall ranch, 3½ miles below Saugus, Cal.

Width, 6 feet; area, 3.8 square feet; mean velocity, 1.39 feet per second; discharge, 5.3 second-feet.

*Santa Clara River near Camulos, Cal.*—A measurement was made October 19 by W. B. Clapp at a point 1 mile above Camulos and 1,000 feet below diversion of Camulos ditch.

Width, 11 feet; area, 4.9 square feet; mean velocity, 2.06 feet per second; discharge, 10.1 second-feet. For total discharge of Santa Clara River at this point add discharge of Camulos ditch.

*Santa Clara River near Santa Paula, Cal.*—A measurement was made October 21 by W. B. Clapp 1 mile above Santa Paula and about 500 feet below diversion of Farmers and Grees canals.

Width, 33 feet; area, 17.4 square feet; mean velocity, 1.55 feet per second; discharge, 27 second-feet. For total diversion of Santa Clara River at this point add discharge of Farmers and Grees canals.

*Santa Clara River near Saticoy, Cal.*—A measurement was made October 21 by W. B. Clapp at a point opposite Saticoy and 200 feet below head of Santa Clara Water and Irrigation Company's canal.

Width, 14 feet; area, 14.7 square feet; mean velocity, 1.63 feet per second; discharge, 24 second-feet. For total discharge of Santa Clara River at this point add discharge of Santa Clara Water and Irrigation Company's canal.

*Santa Clara Water and Irrigation Company's canal near Saticoy, Cal.*—This canal diverts water from the Santa Clara River and is used for the irrigation of Santa Clara ranch near Oxnard, Cal.

Measurement made over weir. Discharge equals 16.7 second-feet.

## SANTA YNEZ RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Santa Ynez River rises in the mountains of Santa Barbara and Ventura counties and flows westerly with a flat grade to the Pacific Ocean, having a length of approximately 75 miles. The Santa Ynez Range of mountains, varying in elevation from 3,000 to 4,000 feet, forms the southern boundary of this drainage basin. The northern divide ranges from 4,500 to 5,500 feet in elevation, culminating in Mount Pinos, the elevation of which is 8,826 feet. The northern part of the watershed is drained by streams running in a southerly direction and uniting with the Santa Ynez River proper, which runs close to the northerly base of the Santa Ynez Mountains, flowing westerly and paralleling the Coast Range. The principal tributary, Mono Creek, enters from the north.

The formation throughout the entire drainage basin consists chiefly of shale and sandstone, the strike being parallel to the coast and the dip nearly vertical, inclining somewhat to the south.

The greater portion of the drainage is sparsely covered with brush and small trees, only a small area on the higher elevations having any considerable growth of timber.

The mean annual precipitation is estimated at 25 inches for the entire area and falls almost entirely in the form of rain.

There are several reservoir sites on Santa Ynez and its tributaries which have been surveyed.

### SANTA YNEZ RIVER NEAR SANTA BARBARA, CAL.

The original station, at which measurements were made during the greater part of 1903, was located about 1 mile above the mouth of Mono Creek. On November 1, 1903, the old station was abandoned and a new station established by L. M. Hyde. It is located at the Gibraltar dam site, 5 miles below the original station, and is below the mouth of Mono Creek. It is 9 miles above the San Marcus ranch and halfway between the old quicksilver mines.

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The channel is straight for 700 feet above and 600 feet below the station. The right bank is low, but is not liable to overflow. The left bank rises abruptly about 20 feet beyond the tree to which the cable is attached. It is not liable to overflow. The bed of the stream is composed of sand and gravel, free from vegetation and bowlders. The cross section is regular and is permanent. The current is swift.

Discharge measurements are made at high water by means of a cable. Measurements can can usually be made by wading. The initial point for soundings is a blaze at the base of the cottonwood tree on the right bank, to which the cable is attached.

The gage is an inclined timber spiked to a cottonwood tree on the right bank. The tree is blazed and graduated above the gage rod for recording stages above the gage. The bench mark is a cross on a bench of a ledge of rock on the left bank, about 100 feet below the cable. Elevation, 13.54 feet above the datum of the gage. The approximate elevation above sea level, as estimated from topographic maps, is 1,200 feet.

Information in regard to this station is contained in Water Supply Papers Nos. 81, 100, and 134 of the United States Geological Survey.

*Daily gage height, in feet, of Santa Ynez River near Santa Barbara, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.3 | 2.5 | 3.1 | 3.25 | 2.65 | 2.4 | 2.05 | 2.0 | 1.9 | 1.8 | 1.8 | 2.05 |
| 2 | 2.3 | 3.6 | 3.05 | 3.25 | 2.7 | 2.4 | 2.05 | 2.0 | 1.9 | 1.8 | 1.8 | 2.05 |
| 3 | 2.25 | 8.4 | 3.0 | 3.2 | 2.65 | 2.4 | 2.05 | 2.0 | 1.85 | 1.8 | 1.8 | 2.05 |
| 4 | 2.25 | 6.8 | 3.0 | 3.15 | 2.6 | 2.4 | 2.05 | 2.0 | 1.85 | 1.8 | 1.8 | 2.05 |
| 5 | 2.25 | 4.0 | 3.05 | 3.15 | 2.6 | 2.4 | 2.05 | 2.0 | 1.85 | 1.8 | 1.8 | 2.05 |
| 6 | 2.25 | 3.9 | 3.1 | 3.1 | 2.6 | 2.4 | 2.05 | 2.0 | 1.85 | 1.8 | 1.85 | 2.05 |
| 7 | 2.2 | 3.75 | 3.0 | 3.1 | 2.6 | 2.4 | 2.05 | 2.0 | 1.85 | 1.8 | 1.85 | 2.05 |
| 8 | 3.8 | 3.7 | 2.9 | 3.05 | 2.6 | 2.4 | 2.05 | 2.0 | 1.85 | 1.8 | 1.85 | 2.05 |
| 9 | 3.7 | 3.65 | 2.9 | 3.05 | 2.6 | 2.35 | 2.05 | 2.0 | 1.85 | 1.8 | 1.85 | 2.05 |
| 10 | 2.6 | 3.65 | 2.85 | 3.05 | 2.6 | 2.35 | 2.05 | 2.0 | 1.85 | 1.8 | 1.85 | 2.05 |
| 11 | 2.55 | 3.6 | 2.9 | 3.0 | 2.6 | 2.35 | 2.05 | 2.0 | 1.85 | 1.8 | 1.85 | 2.05 |
| 12 | 2.5 | 3.6 | 4.7 | 3.05 | 2.6 | 2.3 | 2.05 | 2.0 | 1.85 | 1.8 | 1.9 | 2.05 |
| 13 | 2.45 | 3.6 | 8.9 | 3.0 | 2.55 | 2.3 | 2.05 | 2.0 | 1.85 | 1.8 | 1.9 | 2.05 |
| 14 | 2.4 | 3.55 | 5.65 | 2.95 | 2.55 | 2.25 | 2.05 | 2.0 | 1.85 | 1.8 | 1.9 | 2.05 |
| 15 | 2.45 | 3.4 | 4.65 | 2.95 | 2.55 | 2.25 | 2.05 | 2.0 | 1.85 | 1.8 | 1.9 | 2.05 |
| 16 | 2.5 | 4.45 | 5.3 | 2.9 | 2.55 | 2.2 | 2.05 | 1.95 | 1.85 | 1.8 | 1.9 | 2.05 |
| 17 | 2.45 | 6.55 | 4.65 | 2.9 | 2.55 | 2.2 | 2.05 | 1.95 | 1.85 | 1.8 | 1.9 | 2.05 |
| 18 | 2.4 | 4.0 | 4.4 | 2.9 | 2.5 | 2.2 | 2.05 | 1.95 | 1.85 | 1.8 | 1.9 | 2.05 |
| 19 | 2.4 | 3.75 | 4.15 | 2.85 | 2.5 | 2.15 | 2.05 | 1.95 | 1.85 | 1.8 | 1.9 | 2.05 |
| 20 | 2.4 | 3.7 | 4.0 | 2.85 | 2.5 | 2.15 | 2.05 | 1.95 | 1.85 | 1.8 | 1.9 | 2.05 |
| 21 | 4.25 | 3.65 | 3.8 | 2.85 | 2.5 | 2.15 | 2.05 | 1.95 | 1.85 | 1.8 | 1.9 | 2.05 |
| 22 | 3.15 | 3.5 | 3.75 | 2.8 | 2.5 | 2.1 | 2.05 | 1.95 | 1.85 | 1.8 | 1.9 | 2.05 |
| 23 | 2.9 | 3.4 | 3.65 | 2.8 | 2.5 | 2.1 | 2.05 | 1.95 | 1.8 | 1.8 | 1.9 | 2.05 |
| 24 | 2.8 | 3.3 | 3.6 | 2.8 | 2.5 | 2.1 | 2.05 | 1.9 | 1.8 | 1.8 | 1.9 | 2.05 |
| 25 | 2.75 | 3.2 | 3.55 | 2.75 | 2.45 | 2.1 | 2.05 | 1.9 | 1.8 | 1.8 | 1.9 | 2.05 |
| 26 | 2.65 | 3.15 | 3.5 | 2.75 | 2.45 | 2.1 | 2.0 | 1.9 | 1.8 | 1.8 | 2.0 | 2.05 |
| 27 | 2.65 | 3.1 | 3.4 | 2.85 | 2.45 | 2.1 | 2.0 | 1.9 | 1.8 | 1.8 | 2.1 | 2.05 |
| 28 | 2.6 | 3.1 | 3.4 | 2.75 | 2.45 | 2.1 | 2.0 | 1.9 | 1.8 | 1.8 | 2.1 | 2.05 |
| 29 | 2.6 | ..... | 3.6 | 2.7 | 2.45 | 2.1 | 2.0 | 1.9 | 1.8 | 1.8 | 2.1 | 2.05 |
| 30 | 2.5 | ..... | 3.4 | 2.7 | 2.45 | 2.1 | 2.0 | 1.9 | 1.8 | 1.8 | 2.05 | 2.05 |
| 31 | 2.5 | ..... | 3.3 | ..... | 2.45 | ..... | 2.0 | 1.9 | ..... | 1.8 | ..... | 2.05 |

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*Station rating table for Santa Ynez River near Santa Barbara, Cal., from January 1 to February 2, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.00 | 0.4 | 2.60 | 38 | 3.20 | 154 | 3.80 | 401 |
| 2.10 | 2.8 | 2.70 | 50 | 3.30 | 186 | 3.90 | 451 |
| 2.20 | 6.4 | 2.80 | 65 | 3.40 | 222 | 4.00 | 502 |
| 2.30 | 11.6 | 2.90 | 82 | 3.50 | 263 | | |
| 2.40 | 18.5 | 3.00 | 103 | 3.60 | 306 | | |
| 2.50 | 28 | 3.10 | 126 | 3.70 | 353 | | |

*Station rating table for Santa Ynez River near Santa Barbara, Cal., from February 3 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.80 | 1 | 3.00 | 153 | 4.20 | 875 | 5.80 | 2,790 |
| 1.90 | 2 | 3.10 | 184 | 4.30 | 965 | 6.00 | 3,070 |
| 2.00 | 3 | 3.20 | 220 | 4.40 | 1,065 | 6.20 | 3,360 |
| 2.10 | 5 | 3.30 | 265 | 4.50 | 1,175 | 6.40 | 3,650 |
| 2.20 | 10 | 3.40 | 315 | 4.60 | 1,285 | 6.60 | 3,940 |
| 2.30 | 19 | 3.50 | 370 | 4.70 | 1,395 | 6.80 | 4.230 |
| 2.40 | 30 | 3.60 | 430 | 4.80 | 1,510 | 7.00 | 4,520 |
| 2.50 | 44 | 3.70 | 495 | 4.90 | 1,630 | 7.50 | 5,245 |
| 2.60 | 60 | 3.80 | 565 | 5.00 | 1,750 | 8.00 | 5,970 |
| 2.70 | 79 | 3.90 | 635 | 5.20 | 1,990 | 8.50 | 6,695 |
| 2.80 | 100 | 4.00 | 710 | 5.40 | 2,250 | 9.00 | 7,420 |
| 2.90 | 125 | 4.10 | 790 | 5.60 | 2,510 | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during January, February, and March, 1906.

*Estimated monthly discharge of Santa Ynez River near Santa Barbara, Cal., for 1905.*

[Drainage area, 207 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 635 | 6.4 | 73.8 | 4,538 | 0.357 | 0.412 |
| February | 6,550 | 28.0 | 905 | 50,260 | 4.37 | 4.55 |
| March | 7,275 | 112 | 797 | 49,010 | 3.85 | 4.44 |
| April | 242 | 79 | 143 | 8,509 | .691 | .771 |
| May | 100 | 37 | 52.5 | 3,228 | .254 | .293 |
| June | 30 | 5 | 15.9 | 946 | .077 | .086 |
| July | 4 | 3 | 3.8 | 234 | .018 | .021 |
| August | 3 | 2 | 2.6 | 160 | .013 | .015 |
| September | 2 | 1 | 1.4 | 83 | .0068 | .0076 |
| October | 1 | 1 | 1.0 | 61 | .0048 | .0055 |
| November | 5 | 1 | 2.1 | 125 | .010 | .011 |
| December | 4 | 4 | 4.0 | 246 | .019 | .022 |
| The year | 7,275 | 1.0 | 167 | 117,400 | .806 | 10.63 |

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## SANTA MARIA RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

The Santa Maria River drains the northern slope of the San Rafael Mountains and a limited area of foothill country to the north of this range. It flows in a westerly direction, finally discharging its waters into the Pacific Ocean at Guadalupe about 25 miles south of San Luis Obispo. Its flow is torrential in character, subject to floods of short duration during the rainy period, but being practically dry during the summer months. It has numerous tributaries, the most important of which is the Sisquoc, which enters it about 12 miles above the town of Santa Maria. The gaging station is located about 25 miles above the town of Santa Maria and above most of its important tributaries. The country throughout this basin consists of rolling foothills, with the exception of the higher elevations of the San Rafael Mountains, which reach an elevation of 6,000 to 8,000 feet. The river breaks from the foothills at the point where it is joined by the Sisquoc and flows through the flat country of the Santa Maria Valley for a distance of about 25 miles until it joins the Pacific Ocean at Guadalupe. The formation throughout this basin is of shale, sandstone, and conglomerate, with a good covering of heavy clay soil. There is considerable growth of timber on the higher elevations of the San Rafael Mountains, but over most of the area the growth of timber is light, with large areas of brush and grass. The pasturage of stock is carried on extensively throughout the basin. There are no diversions along this stream for irrigation although tunnel work has been attempted above Santa Maria for the development of underground water, with poor results. There are numerous wells in the vicinity of Santa Maria which produce considerable water for the irrigation of land in that locality, the soil being very deep and of exceptional quality, susceptible to the highest state of cultivation. The mean precipitation in this drainage basin is probably about 25 inches. The greatest rainfall occurs on the lower elevations near the coast. The higher elevations receive some snowfall, which melts early in the spring and does not tend to keep up the flow of the stream through the summer.

### SANTA MARIA RIVER NEAR SANTA MARIA, CAL.

This station was established October 22, 1903, by W. B. Clapp. It is located near the ranch house on Dutard's ranch, 21 miles above Santa Maria, Cal., a station on the Pacific Coast Railway. It is reached by driving from Santa Maria.

The channel is slightly curved for 300 feet above and curved for 1,000 feet below the station. The water is swift at medium and flood stages.

The right bank is high and rocky, and not liable to overflow. The left bank is low, covered with scattering poplar trees, but not liable to overflow. The bed of the stream is composed of sand and gravel. A portion of the bed is covered with a light growth of low brush. The channel is not liable to much change.

At low and medium water discharge measurements are made with meter by wading. During high water velocities are measured by means of floats. For this purpose two wires are stretched across the stream 254 feet apart. The rise in the channel above the upper wire is 0.40 foot in 100 feet, and below the upper wire it is 0.57 foot in 100 feet. The initial points for soundings are blazes on the poplar trees on the left bank, to which the wires are attached.

The gage is an inclined staff, fastened to a rock ledge at the right bank. During 1905 the gage was read once each day by James A. Thompson. The bench mark is a spike driven near the ground into the south side of the poplar tree to which the upper wire is fastened on the left bank of the stream; elevation, 9.65 feet above the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 100 and 134 of the United States Geological Survey.

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*Discharge measurements of Santa Maria River near Santa Maria, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| February 2 | E. C. La Rue | 34 | 30 | 2.67 | 3.30 | 80 |
| March 6 | O. W. Peterson | 24 | 22 | 2.14 | 2.70 | 47 |
| March 21 | do | 40 | 28 | 2.39 | 1.20 | 67 |

*Daily gage height, in feet, of Santa Maria River near Santa Maria, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.5 | 2.6 | 2.05 | 0.9 | 0.8 | 0.65 | 0.7 | 0.6 | 0.5 | 0.6 | 0.75 | 0.85 |
| 2 | 3.0 | 3.8 | 2.05 | .9 | 1.1 | .65 | .7 | .6 | .5 | .6 | .75 | .85 |
| 3 | 2.9 | 6.0 | 2.05 | .9 | 1.0 | .7 | .7 | .6 | .5 | .6 | .75 | .85 |
| 4 | 2.7 | 5.65 | 2.05 | .9 | .85 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 5 | 2.7 | 5.0 | 2.05 | .9 | .8 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 6 | 2.7 | 5.0 | 2.7 | .9 | .8 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 7 | 2.7 | 3.5 | 2.65 | .85 | .8 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 8 | 2.7 | 3.2 | 2.5 | .85 | 1.2 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 9 | 2.7 | 3.0 | 2.35 | .85 | 1.25 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 10 | 2.7 | 2.9 | 2.2 | .85 | 1.0 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 11 | 2.7 | 2.85 | 2.2 | .85 | .9 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 12 | 2.65 | 2.8 | 2.2 | .85 | .9 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 13 | 2.65 | 2.75 | 10.0 | .85 | .85 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 14 | 2.65 | 2.75 | a 5.0 | .85 | .85 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 15 | 2.65 | 2.65 | a 4.5 | .85 | .8 | .7 | .7 | .6 | .5 | .65 | .75 | .8 |
| 16 | 2.7 | 3.0 | a 4.0 | .85 | .8 | .7 | .7 | .6 | .5 | .7 | .75 | .8 |
| 17 | 2.65 | 4.1 | a 4.0 | .85 | .8 | .7 | .65 | .6 | .5 | .7 | .75 | .8 |
| 18 | 2.65 | 5.95 | a 3.5 | .85 | .8 | .7 | .65 | .6 | .5 | .7 | .75 | .8 |
| 19 | 2.65 | 4.0 | a 3.5 | .85 | .8 | .7 | .65 | .6 | .5 | .7 | .75 | .85 |
| 20 | 2.65 | 2.6 | a 2.0 | .85 | .8 | .7 | .65 | .6 | .5 | .7 | .75 | .85 |
| 21 | 3.0 | 2.4 | 1.2 | .85 | .8 | .7 | .65 | .6 | .5 | .7 | .75 | .85 |
| 22 | 2.8 | 2.35 | 1.1 | .85 | .75 | .7 | .65 | .6 | .5 | .7 | .75 | .85 |
| 23 | 2.7 | 2.25 | 1.05 | .85 | .75 | .7 | .65 | .6 | .5 | .7 | .75 | .85 |
| 24 | 2.7 | 2.15 | 1.05 | .85 | .7 | .7 | .65 | .6 | .5 | .7 | .75 | .85 |
| 25 | 2.65 | 2.15 | 1.0 | .85 | .65 | .7 | .65 | .55 | .7 | .75 | .75 | .85 |
| 26 | 2.65 | 2.15 | 1.0 | .85 | .6 | .7 | .65 | .55 | .7 | .75 | .75 | .8 |
| 27 | 2.65 | 2.1 | 1.0 | .85 | .6 | .7 | .65 | .55 | .65 | .75 | .75 | .8 |
| 28 | 2.65 | 2.05 | 1.2 | .85 | .6 | .7 | .65 | .55 | .6 | .75 | .85 | .8 |
| 29 | 2.65 | ..... | 1.2 | .8 | .6 | .7 | .65 | .5 | .6 | .75 | .85 | .85 |
| 30 | 2.6 | ..... | 1.1 | .8 | .65 | .7 | .6 | .5 | .6 | .75 | .85 | .85 |
| 31 | 2.6 | ..... | 1.0 | ..... | .65 | ..... | .6 | .5 | ..... | .75 | ..... | .85 |

a Estimated.



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[illegible] *Santa Maria River near Santa Maria, Cal., from January [illegible] February 2, 1905.*

| [illegible] | [illegible] | [illegible] | Discharge | Gage height. | Discharge | Gage height. | Discharge |
|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| [illegible] | [illegible] | [illegible] | 13 | 3.30 | 67 | 3.70 | [illegible] |
| [illegible] | [illegible] | [illegible] | 18 | 3.30 | 82 | 3.80 | [illegible] |
| [illegible] | [illegible] | [illegible] | 25 | 3.40 | 100 | 3.90 | [illegible] |
| [illegible] | [illegible] | [illegible] | 33 | 3.50 | 122 | 4.00 | [illegible] |
| [illegible] | [illegible] | [illegible] | 43 | 3.60 | 146 | 4.10 | [illegible] |
| [illegible] | [illegible] | [illegible] | 54 | | | | |

[illegible] *River near Santa Maria, Cal., from February [illegible] March 12, 1905.*

| [illegible] | [illegible] | [illegible] | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| [illegible] | [illegible] | [illegible] | [illegible] | 3.70 | 285 | 4.70 | [illegible] |
| [illegible] | [illegible] | [illegible] | 39 | 3.80 | 335 | 4.80 | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | 3.90 | 385 | 4.90 | 1,[illegible] |
| [illegible] | [illegible] | [illegible] | 67 | 4.00 | 440 | 5.00 | [illegible] |
| [illegible] | [illegible] | [illegible] | 105 | 4.10 | 500 | 5.20 | 1,[illegible] |
| [illegible] | [illegible] | [illegible] | 125 | 4.20 | 565 | 5.40 | 1,[illegible] |
| [illegible] | [illegible] | [illegible] | 147 | 4.30 | 630 | 5.60 | 1,[illegible] |
| [illegible] | [illegible] | [illegible] | 173 | 4.40 | 700 | 5.80 | 1,[illegible] |
| [illegible] | [illegible] | [illegible] | 205 | 4.50 | 770 | 6.00 | 1,[illegible] |
| [illegible] | [illegible] | [illegible] | 242 | 4.60 | 840 | | |

[illegible] *River near Santa Maria, Cal., from March 13 [illegible] December 31, 1905.*

| [illegible] | [illegible] | [illegible] | Discharge. | Gage height. | Discharge. | Gage height. | Discharge |
|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| [illegible] | [illegible] | [illegible] | 250 | 4.00 | 1,070 | 7.00 | 3,380 |
| [illegible] | [illegible] | [illegible] | 280 | 4.20 | 1,185 | 7.20 | 3,450 |
| [illegible] | [illegible] | [illegible] | 310 | 4.40 | 1,305 | 7.40 | 3,650 |
| [illegible] | [illegible] | [illegible] | 340 | 4.60 | 1,435 | 7.60 | 3,870 |
| [illegible] | [illegible] | [illegible] | 375 | 4.80 | 1,565 | 7.80 | 4,100 |
| [illegible] | [illegible] | [illegible] | 410 | 5.00 | 1,700 | 8.00 | 4,350 |
| [illegible] | [illegible] | [illegible] | 445 | 5.20 | 1,840 | 8.20 | 4,640 |
| [illegible] | [illegible] | [illegible] | 480 | 5.40 | 1,980 | 8.40 | 4,970 |
| [illegible] | [illegible] | [illegible] | 520 | 5.60 | 2,130 | 8.60 | 5,340 |
| [illegible] | [illegible] | [illegible] | 560 | 5.80 | 2,280 | 8.80 | 5,750 |
| [illegible] | [illegible] | [illegible] | 600 | 6.00 | 2,430 | 9.00 | 6,200 |
| [illegible] | [illegible] | [illegible] | 690 | 6.20 | 2,585 | 10.00 | 10,000 |
| [illegible] | [illegible] | [illegible] | 780 | 6.40 | 2,745 | | |
| [illegible] | [illegible] | [illegible] | 875 | 6.60 | 2,910 | | |
| [illegible] | [illegible] | [illegible] | 975 | 6.80 | 3,080 | | |

[illegible] of the rating curve is based on slope measurements.

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*ated monthly discharge of Santa Maria River near Santa Maria, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| ..... | 122 | 13 | 22.5 | 1,384 |
| ..... | 1,915 | 6 | 361 | 20,050 |
| ..... | 10,000 | 6 | 574 | 35,290 |
| ..... | 18 | 10 | 14.5 | 863 |
| ..... | 74 | 3 | 15.5 | 953 |
| ..... | 6 | 4 | 5.9 | 352 |
| ..... | 6 | 3 | 5.0 | 307 |
| ..... | 3 | 1 | 2.7 | 166 |
| r..... | 6 | 1 | 1.6 | 96 |
| ..... | 8 | 3 | 5.4 | 332 |
| r..... | 14 | 8 | 8.6 | 512 |
| r..... | 14 | 10 | 11.7 | 719 |
| e year..... | 10,000 | 1 | 85.7 | 61,020 |

—Estimates during high-water periods are approximate only.

## SALINAS RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Arroyo Seco is the most northern tributary of any size of the Salinas River, and rises slopes of the highest portion of the Santa Lucia Range, one of the ranges that go to up the Coast Range of California extending in a general southeast direction from San isco Bay. The upper valleys of this stream are far back in the range, surrounded by mountains.

e drainage area of the Arroyo Seco is almost entirely made up of sharp ridges and V- d canyons. The western portion is well covered with brush and trees of medium size. rd the east this growth decreases until at the Salinas Valley the country is bare. The m beds of this area fall rapidly, the Arroyo Seco rising at an elevation of nearly 6,000 and discharging into the Salinas at an elevation of 170 feet.

low the gaging station several canals divert water from this stream before it reaches the d wash of sand and gravel on the flat floor of the Salinas Valley, into which it sinks dur- the dry season and from which it receives its name "Arroyo Seco."

here are five reservoir sites on the stream and its tributaries, of more or less value as sible storage reservoirs, that have already been surveyed.

his portion of the range undoubtedly receives as great rainfall as any other locality in s region, and it is estimated that the average annual precipitation is from 30 to 50 inches l falls almost entirely in the form of rain.

### ARROYO SECO NEAR SOLEDAD, CAL.

The original gaging station on this stream was established by W. W. Cockins, jr., in ecember, 1900, at Foster's ranch, near Piney, Cal. High water of January, 1901, enlarged a old side channel, dividing the stream into two channels. The gaging station was then moved to Pettitt's ranch, 4 miles below the old station.

The channel is straight for 400 feet above and below the station. The right bank is low, wooded, and subject to overflow. The left bank is high, rocky, and not subject to overflow. The bed of the stream is composed of gravel and is not subject to much change.

Discharge measurements are made by means of a cable and car. The initial point for soundings is on the left bank.

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The gage rod is in two sections. The low-water section is placed 400 feet above the cable on the right bank; the high-water section is fastened to a sycamore tree above the cable and about 250 feet from the right bank of the low-water channel. During 1905 the gage was read by Mrs. Charles Pettitt. The bench mark is a spike in the tree to which the high-water section of the gage is fastened; elevation, 15.00 feet above the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 100, and 134 of the United States Geological Survey.

*Discharge measurements of Arroyo Seco River near Soledad, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 31 | La Rue and Pettitt | 122 | 123 | 1.04 | 5.91 | 128 |
| February 2 | Charles Pettitt | 130 | 410 | 3.84 | 8.80 | 1,574 |
| February 3 | do | 124 | 281 | 3.05 | 7.50 | 856 |
| February 5 | do | 125 | 254 | 3.06 | 7.35 | 778 |
| February 16 | do | 125 | 212 | 2.29 | 6.82 | 486 |
| February 17 | do | 133 | 423 | 4.32 | 8.95 | 1,829 |
| March 11 | do | 120 | 135 | 1.05 | 5.90 | 142 |
| March 13 | do | 133 | 484 | 4.65 | 10.05 | 2,253 |
| March 16 | do | 128 | 327 | 4.02 | 8.00 | 1,315 |
| March 17 | do | 128 | 288 | 2.91 | 7.50 | 838 |
| March 19 | do | 133 | 455 | 4.90 | 9.30 | 2,233 |
| March 29 | do | 125 | 248 | 2.36 | 7.05 | 585 |
| April 9 | do | 123 | 158 | 1.57 | 6.10 | 248 |
| April 16 | do | 123 | 150 | 1.40 | 6.09 | 210 |
| April 19 | do | 123 | 151 | 1.59 | 6.16 | 240 |
| April 29 | do | 122 | 117 | 1.07 | 5.95 | 125 |
| May 7 | do | 130 | 351 | 3.75 | 8.30 | 1,317 |
| May 8 | do | 125 | 241 | 2.86 | 7.12 | 689 |
| May 28 | do | 123 | 107 | 1.15 | 5.93 | 123 |
| June 4 | do | 123 | 113 | 1.03 | 5.83 | 116 |
| June 12 | do | 122 | 95 | .82 | 5.75 | 78 |
| June 18 | do | 122 | 89 | .76 | 5.70 | 68 |
| Do | do | 48 | 63 | 1.24 | 5.70 | 78 |
| June 24 | do | 43 | 54 | 1.00 | 5.62 | 54 |
| July 3 | do | 41 | 49 | .80 | 5.55 | 39 |
| July 9 | do | 40 | 46 | .61 | 5.48 | 28 |
| July 15 | do | 38 | 42 | .57 | 5.45 | 24 |
| July 23 | do | 35 | 39 | .54 | 5.42 | 21 |
| July 29 | do | 36 | 37 | .43 | 5.40 | 16 |
| August 6 | do | 34 | 35 | .37 | 5.38 | 13 |
| August 10 | do | 27 | 24 | .33 | 5.33 | 8 |

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*Daily gage height, in feet, of Arroyo Seco River near Soledad, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.1 | 8.4 | 6.15 | 6.5 | 5.9 | 5.85 | 5.6 | 5.4 | 5.2 | 5.25 | 5.35 | 5.65 |
| 2 | 5.9 | 8.6 | 6.1 | 6.45 | 6.55 | 5.85 | 5.55 | 5.4 | 5.2 | 5.25 | 5.35 | 5.6 |
| 3 | 5.8 | 7.45 | 6.05 | 6.4 | 6.2 | 5.8 | 5.5 | 5.4 | 5.2 | 5.25 | 5.35 | 5.55 |
| 4 | 5.75 | 7.4 | 6.0 | 6.35 | 6.05 | 5.85 | 5.5 | 5.4 | 5.2 | 5.25 | 5.35 | 5.5 |
| 5 | 5.7 | 7.35 | 6.0 | 6.3 | 6.0 | 5.8 | 5.5 | 5.4 | 5.2 | 5.25 | 5.35 | 5.5 |
| 6 | 5.7 | 7.2 | 6.0 | 6.25 | 6.0 | 5.8 | 5.5 | 5.4 | 5.2 | 5.25 | 5.35 | 5.5 |
| 7 | 5.65 | 7.0 | 5.95 | 6.25 | 7.9 | 5.8 | 5.5 | 5.35 | 5.2 | 5.25 | 5.35 | 5.5 |
| 8 | 5.6 | 6.8 | 5.9 | 6.2 | 7.2 | 5.8 | 5.5 | 5.35 | 5.2 | 5.25 | 5.35 | 5.5 |
| 9 | 5.8 | 6.65 | 5.9 | 6.1 | 6.8 | 5.8 | 5.5 | 5.35 | 5.2 | 5.25 | 5.35 | 5.5 |
| 10 | 6.0 | 6.55 | 5.9 | 6.15 | 6.6 | 5.8 | 5.5 | 5.35 | 5.2 | 5.25 | 5.35 | 5.5 |
| 11 | 5.9 | 6.45 | 5.9 | 6.1 | 6.45 | 5.75 | 5.45 | 5.35 | 5.2 | 5.25 | 5.35 | 5.5 |
| 12 | 5.8 | 6.35 | 6.55 | 6.1 | 6.4 | 5.75 | 5.45 | 5.35 | 5.2 | 5.25 | 5.35 | 5.5 |
| 13 | 5.8 | 6.3 | 10.1 | 6.1 | 6.3 | 5.7 | 5.45 | 5.35 | 5.2 | 5.25 | 5.35 | 5.5 |
| 14 | 5.9 | 6.25 | 7.85 | 6.1 | 6.2 | 5.7 | 5.45 | 5.35 | 5.2 | 5.25 | 5.35 | 5.5 |
| 15 | 5.9 | 6.2 | 7.5 | 6.05 | 6.2 | 5.7 | 5.45 | 5.35 | 5.2 | 5.25 | 5.35 | 5.5 |
| 16 | 6.95 | 6.8 | 8.0 | 6.1 | 6.15 | 5.7 | 5.45 | 5.3 | 5.25 | 5.25 | 5.35 | 5.5 |
| 17 | 6.3 | 8.5 | 7.6 | 6.05 | 6.1 | 5.7 | 5.45 | 5.3 | 5.25 | 5.3 | 5.4 | 5.5 |
| 18 | 6.1 | 7.45 | 7.3 | 6.0 | 6.1 | 5.7 | 5.45 | 5.3 | 5.25 | 5.3 | 5.4 | 5.55 |
| 19 | 6.2 | 7.05 | 9.1 | 6.2 | 6.05 | 5.7 | 5.45 | 5.3 | 5.25 | 5.3 | 5.4 | 5.6 |
| 20 | 6.1 | 6.9 | 7.6 | 6.1 | 6.05 | 5.7 | 5.4 | 5.3 | 5.2 | 5.3 | 5.4 | 5.6 |
| 21 | 6.5 | 6.6 | 7.35 | 6.05 | 6.0 | 5.7 | 5.4 | 5.3 | 5.2 | 5.3 | 5.4 | 5.6 |
| 22 | 6.2 | 6.5 | 7.1 | 6.05 | 6.0 | 5.65 | 5.4 | 5.3 | 5.2 | 5.3 | 5.4 | 5.6 |
| 23 | 6.1 | 6.4 | 6.9 | 6.0 | 5.95 | 5.65 | 5.4 | 5.3 | 5.2 | 5.35 | 5.4 | 5.6 |
| 24 | 6.05 | 6.35 | 6.75 | 6.0 | 5.9 | 5.65 | 5.4 | 5.3 | 5.2 | 5.35 | 5.5 | 5.55 |
| 25 | 6.1 | 6.3 | 6.7 | 6.0 | 5.9 | 5.6 | 5.4 | 5.3 | 5.2 | 5.35 | 5.65 | 5.55 |
| 26 | 6.0 | 6.25 | 6.65 | 6.0 | 5.95 | 5.6 | 5.4 | 5.3 | 5.2 | 5.35 | 5.5 | 5.5 |
| 27 | 6.0 | 6.2 | 6.55 | 6.0 | 5.95 | 5.6 | 5.4 | 5.25 | 5.2 | 5.35 | 5.5 | 5.5 |
| 28 | 6.0 | 6.2 | 6.5 | 6.0 | 5.95 | 5.6 | 5.4 | 5.25 | 5.2 | 5.35 | 5.75 | 5.5 |
| 29 | 5.95 | ..... | 7.5 | 5.95 | 5.9 | 5.6 | 5.4 | 5.25 | 5.2 | 5.35 | 5.6 | 5.55 |
| 30 | 5.9 | ..... | 6.65 | 5.95 | 5.9 | 5.6 | 5.4 | 5.25 | 5.2 | 5.35 | 5.9 | 5.5 |
| 31 | 5.9 | ..... | 6.6 | ..... | 5.85 | ..... | 5.4 | 5.25 | ..... | 5.3 | ..... | 5.5 |

*Station rating table for Arroyo Seco River near Soledad, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 5.20 | 2 | 6.30 | 265 | 7.40 | 800 | 9.00 | 1,900 |
| 5.30 | 6 | 6.40 | 305 | 7.50 | 860 | 9.20 | 2,060 |
| 5.40 | 15 | 6.50 | 345 | 7.60 | 920 | 9.40 | 2,225 |
| 5.50 | 30 | 6.60 | 390 | 7.70 | 980 | 9.60 | 2,400 |
| 5.60 | 50 | 6.70 | 435 | 7.80 | 1,045 | 9.80 | 2,580 |
| 5.70 | 70 | 6.80 | 480 | 7.90 | 1,110 | 10.00 | 2,760 |
| 5.80 | 95 | 6.90 | 530 | 8.00 | 1,175 | 10.20 | 2,945 |
| 5.90 | 125 | 7.00 | 580 | 8.20 | 1,310 | 10.40 | 3,135 |
| 6.00 | 155 | 7.10 | 635 | 8.40 | 1,450 | | |
| 6.10 | 190 | 7.20 | 690 | 8.60 | 1,595 | | |
| 6.20 | 225 | 7.30 | 745 | 8.80 | 1,745 | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on 31 discharge measurements made during 1905. It is well defined between gage heights 5.3 feet and 9.5 feet.

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*Estimated monthly discharge of Arroyo Seco River near Soledad, Cal., for 1905*

[Drainage area, 215 square miles.]

| Month | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 555 | 50 | 160 | 9,838 | 0.744 | 0.858 |
| February | 1,595 | 225 | 556 | 30,880 | 2.59 | 2.70 |
| March | 2,850 | 125 | 586 | 36,030 | 2.73 | 3.15 |
| April | 345 | 140 | 202 | 12,020 | .940 | 1.05 |
| May | 1,110 | 110 | 246 | 15,130 | 1.14 | 1.31 |
| June | 110 | 50 | 75.6 | 4,499 | .352 | .393 |
| July | 50 | 15 | 22.8 | 1,402 | .106 | .122 |
| August | 15 | 4 | 8.6 | 529 | .040 | .046 |
| September | 4 | 2 | 2.3 | 137 | .011 | .012 |
| October | 10 | 4 | 6.1 | 375 | .028 | .032 |
| November | 125 | 10 | 22.4 | 1,333 | .104 | .116 |
| December | 60 | 30 | 36.5 | 2,245 | .170 | .196 |
| The year | 2,850 | 2 | 160 | 114,400 | .746 | 9.98 |

## MISCELLANEOUS MEASUREMENTS IN SOUTHERN CALIFORNIA.

The following is a list of miscellaneous discharge measurements made in Riverside and San Diego counties during 1905:

*Cottonwood Creek near Jamul, Cal.*—This stream rises in the Coast Range in the southeastern part of San Diego County, and flowing in a southwesterly direction discharges into Tiajuana River below the California-Mexico boundary line. The following discharge measurements were made at the Barrett Dam. The gage is a 2-by-4 inch vertical timber painted white and graduated to feet and hundredths. It is nailed to the timber wall on the left bank of the stream at the concrete dam. No bench mark was established, as the zero of the rod is set level with the top of the concrete dam.

November 18: Width, 2.7 feet; area, 0.5 square foot; mean velocity, 1.00 foot per second; discharge, 0.5 second-foot.

December 14: Width, 5 feet; area, 1.6 square feet; mean velocity, 0.69 foot per second; gage height, 0.05 foot; discharge, 1.1 second-feet.

*Temecula Creek near Temecula, Cal.*—This creek rises in the Coast Range in the southeastern part of Riverside County, and flowing in a southwesterly direction discharges into the Pacific Ocean near Oceanside, Cal. The following discharge measurements were made on this stream during 1905:

At Pauba dam site, 12 miles above Temecula, Cal., November 14: Width, 7.5 feet; area, 2 square feet; mean velocity, 1.25 feet per second; discharge, 2.5 second-feet.

At Temecula Bridge, 1 mile below Temecula, Cal., November 14: Width, 11 feet; area, 5.4 square feet; mean velocity, 1.07 feet per second; gage height, 3.10 feet; discharge, 5.8 second-feet.

December 30: Width, 9 feet; area, 3.5 square feet; mean velocity, 1.32 feet per second; gage height, 2.98 feet; discharge, 4.6 second-feet.

A gage was placed on the Temecula Bridge consisting of a 2-by-6 inch vertical timber, graduated to feet and hundredths. It is fastened to the downstream pier near the right bank of the stream. No bench mark was established.

*San Diego River near Lakeside, Cal.*—This stream rises in the Coast Range in the eastern part of San Diego County, and flowing in a southwesterly direction discharges in the Pacific Ocean near San Diego, Cal. A measurement was made at the concrete dam of the San Diego Flume Company, at the head of that company's flume.

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November 23: Width, 6 feet; area, 1.0 square foot; mean velocity, 1.90 feet per second; discharge, 1.9 second-feet.

*Santa Ysabel River near San Pasqual, Cal.*—This stream rises in the eastern part of San Diego County, and flowing in a southwesterly direction discharges into the Pacific Ocean near Del Mar, Cal. The lower portion of this river is known as the San Dieguito River. The following measurements were made during 1905 at the upper end of the San Pasqual Valley. The gage consists of a 2-by-4 inch inclined timber, graduated to feet and hundredths, and bolted to a large granite bowlder on the left bank of the stream. The bench mark is on top of the bowlder to which the gage is bolted. It is marked with a circle of white paint. Its elevation is 11.66 feet above the zero of the gage.

November 21: Width, 5 feet; area, 2.2 square feet; mean velocity, 2.05 feet per second; discharge, 4.5 second-feet.

November 28: Width, 83 feet; area, 24 square feet; mean velocity, 1.70 feet per second; gage height, 3.72 feet; discharge, 41 second-feet.

December 21: Width, 24 feet; area, 7.2 square feet; mean velocity, 1.44 feet per second; gage height, 3.55 feet; discharge, 10.4 second-feet.

*Sweetwater River near Descanso, Cal.*—This stream rises in the southeastern part of San Diego County, and flowing in a southwesterly direction discharges into San Diego Bay near National City. The following measurements were made during 1905, 1 mile below Descanso. The gage is a 2-by-6 inch vertical timber, graduated to feet and hundredths. It is bolted to a granite bowlder on the left bank of the stream. The bench mark is the highest point on the large bowlder to which the gage is fastened. It is marked with a circle of white paint, and its elevation is 5 feet above the zero of the gage.

September 11: Measured by Weir; discharge, 0.37 second-foot.

November 21: Width, 3 feet; area, 0.9 square foot; mean velocity, 1.22 feet per second; gage height, 3.54 feet; discharge, 1.1 second-feet.

December 10: Width, 6 feet; area, 1.9 square feet; mean velocity, 1.35 feet per second; gage height, 3.62 feet; discharge, 2.5 second-feet.

## SAN FRANCISCO BAY DRAINAGE BASIN.

### GENERAL FEATURES.

Sacramento River, rising in northern California and flowing south, and San Joaquin River, rising in the southern Sierras and flowing north, drain the western slope of the Sierra Nevada and the eastern slope of the Coast Range north of San Francisco. They meet near Suisun Bay, finally discharging their waters into the Pacific Ocean through San Francisco Bay.

### SACRAMENTO RIVER.

#### DESCRIPTION OF RIVER.

Sacramento River is the principal river of California, and drains all of the territory south of Mount Shasta and between the Coast Range and Trinity Range on the west and the Sierra Nevadas on the east. The portion of the drainage basin above the gaging station which is located near Red Bluff, Cal., extends from the Trinity Mountains on the west to Warner Mountains near the California-Nevada State line on the east. The watershed on the west from the Trinity Mountains is comparatively narrow, being only from 10 to 35 miles in width, and furnishes a very small proportion of the discharge of this river, but from the east Pit River, which is the most important tributary, drains a large area extending about 120 miles east from the Sacramento River and between Mount Shasta on the north and Lassen Peak on the south. The greater portion of this basin is composed of lava, and shows other evidences of volcanic activity, such as volcanic cones and craters. Nearly all the streams tributary to Pit River have their origin in large springs, many of which discharge several hundred second-feet. The most important tributary of the Pit is the McCloud

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River, draining the southeastern slope of Mount Shasta. It derives its waters principally from the melting of the snow on the high elevations of this mountain. The western portion of the watershed extending along the Trinity Range is well timbered, as is also that portion of the drainage area in the Sierra Nevadas lying between Mount Shasta and Lassen Peak. Farther east, however, there is little or no forest covering, and the country is used extensively for pasturage. The rainfall is very unequally distributed, varying from less than 10 inches in the eastern portion of the basin to 50 inches along the northern and western portion. Below the gaging station the river enters the Sacramento Valley, through which it flows on a comparatively light grade until it reaches Suisun Bay. During the winter months, when the Sacramento and its tributaries are in flood, large areas of the Sacramento Valley are overflowed. The floods which occur in the latter part of the rainy season, and after these large overflow areas or basins are filled, cause great damage in the lower portion of the valley.

### SACRAMENTO RIVER NEAR RED BLUFF, CAL.

The gaging station at Jellys Ferry, which is located about 12 miles above the town of Red Bluff, was established April 30, 1895. The right bank of the river is high, but the left bank is liable to overflow when the river rises above the 25-foot mark. The river has been known to reach the 35-foot mark. Because of the liability to overflow it was deemed advisable to select a new gaging station, where the water at flood stage could be more confined. A point in Iron Canyon, where the river had been gaged by the State engineering department in 1879 and by commissioner of public works in 1893–94, was chosen as a new gaging station.

The river at this point in lower portion of Iron Canyon, 4 miles above Red Bluff, has a direct course for 2 or 3 miles. The width between banks at low water is about 500 feet. The depth of water at low stages averages 6 feet, with a maximum depth of 9 feet. The banks are steep and firm. The river flows in a bed of coarse gravel and cobbles, with here and there a small bowlder. The bed rock is lava.

Discharge measurements are made from a cable 600 feet in span, which is anchored in the lava rock which forms the wall of the canyon.

The river stage rod used by commissioner of public works was still in place, and has been used in making river height observations since January 28, 1902, the date upon which the observations were begun. A second set of gage rods were placed on the right bank 3,200 feet below the gaging station January 1, 1904, as no observer could be obtained to continue readings of the station gage. By synchronous readings of the lower gages and the station gage the actual readings for this lower gage have been converted into equivalent readings for the station gage. On September 28, 1904, it was necessary to move the lower gage rods to the left bank about 4,000 feet below the gaging station. The actual readings of this set of gage rods have also been converted into equivalent readings for the station gage. During 1905 the gage was read twice each day by Fred Weeks. All reported gage heights are those determined for the station gage. Bench marks were established as follows: (1) A nail in the crotch of sycamore tree to which the third section of the gage is fastened; elevation, 8.355 feet. (2) Point of rock marked with heavy ring of white paint 7.1 feet south of eye-bolt on left bank; elevation, 47.75 feet. (3) A point marked with ring of white paint 45 feet north of 10-foot mark on cable; elevation 38.01 feet. (4) Eye-bolt on left bank; elevation 44.80 feet. (5) Point on rock under left cable support marked with circle of white paint; elevation, 27.59 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 100, and 134 of the United States Geological Survey.

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*Discharge measurements of Sacramento River near Red Bluff, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| August 5 | Peterson and Lee | 448 | 3,520 | 1.48 | 1.49 | 5,208 |
| August 30 | C. H. Lee | 497 | 3,404 | 1.48 | 1.34 | 5,043 |

*Daily gage height, in feet, of Sacramento River near Red Bluff, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.2 | 8.9 | 4.85 | 8.05 | 4.05 | 3.0 | 1.95 | 1.45 | 1.25 | 1.3 | 1.3 | 1.75 |
| 2 | 6.15 | 15.85 | 4.75 | 7.8 | 4.3 | 3.0 | 1.95 | 1.45 | 1.25 | 1.3 | 1.3 | 1.55 |
| 3 | 4.8 | 13.3 | 4.6 | 7.55 | 4.1 | 3.0 | 1.9 | 1.45 | 1.25 | 1.3 | 1.3 | 1.55 |
| 4 | 4.7 | 11.35 | 4.55 | 7.1 | 3.9 | 3.0 | 1.9 | 1.45 | 1.25 | 1.25 | 1.3 | 1.55 |
| 5 | 4.3 | 10.15 | 4.5 | 6.8 | 3.7 | 3.0 | 1.9 | 1.45 | 1.25 | 1.25 | 1.3 | 1.55 |
| 6 | 4.0 | 8.95 | 4.4 | 6.45 | 3.7 | 3.0 | 1.8 | 1.45 | 1.25 | 1.25 | 1.4 | 1.55 |
| 7 | 3.75 | 8.15 | 4.3 | 6.25 | 4.1 | 2.85 | 1.75 | 1.4 | 1.25 | 1.3 | 1.4 | 1.55 |
| 8 | 3.55 | 7.4 | 4.2 | 5.95 | 5.5 | 2.9 | 1.7 | 1.4 | 1.25 | 1.3 | 1.4 | 1.55 |
| 9 | 3.45 | 6.8 | 4.15 | 5.75 | 4.95 | 2.85 | 1.75 | 1.4 | 1.25 | 1.3 | 1.4 | 1.55 |
| 10 | 3.35 | 6.4 | 4.05 | 5.45 | 4.6 | 2.85 | 1.75 | 1.4 | 1.25 | 1.3 | 1.4 | 1.55 |
| 11 | 3.2 | 6.0 | 4.05 | 5.25 | 3.85 | 2.7 | 1.7 | 1.4 | 1.25 | 1.3 | 1.4 | 1.55 |
| 12 | 3.1 | 5.55 | 4.9 | 5.0 | 4.15 | 2.7 | 1.7 | 1.3 | 1.25 | 1.3 | 1.45 | 1.55 |
| 13 | 3.85 | 5.2 | 10.25 | 4.85 | 4.15 | 2.65 | 1.7 | 1.3 | 1.25 | 1.25 | 1.45 | 1.7 |
| 14 | 14.35 | 4.9 | 13.55 | 4.75 | 3.9 | 2.6 | 1.7 | 1.3 | 1.25 | 1.3 | 1.45 | 1.55 |
| 15 | 9.8 | 4.75 | 11.15 | 4.7 | 3.85 | 2.55 | 1.7 | 1.3 | 1.25 | 1.3 | 1.45 | 1.55 |
| 16 | 9.5 | 4.55 | 10.7 | 5.45 | 3.85 | 2.5 | 1.7 | 1.3 | 1.25 | 1.3 | 1.45 | 1.55 |
| 17 | 7.95 | 4.55 | 9.7 | 4.95 | 4.0 | 2.4 | 1.7 | 1.3 | 1.25 | 1.3 | 1.45 | 1.7 |
| 18 | 6.85 | 4.5 | 8.25 | 4.75 | 3.85 | 2.35 | 1.6 | 1.3 | 1.25 | 1.3 | 1.45 | 1.8 |
| 19 | 7.3 | 5.25 | 11.4 | 5.2 | 3.75 | 2.35 | 1.6 | 1.3 | 1.25 | 1.3 | 1.45 | 2.1 |
| 20 | 7.05 | 8.2 | 10.3 | 5.0 | 3.6 | 2.3 | 1.55 | 1.3 | 1.25 | 1.3 | 1.55 | 2.1 |
| 21 | 9.2 | 7.95 | 11.1 | 4.85 | 3.5 | 2.3 | 1.55 | 1.3 | 1.25 | 1.3 | 1.55 | 1.9 |
| 22 | 14.3 | 7.2 | 11.2 | 4.7 | 3.4 | 2.25 | 1.55 | 1.3 | 1.25 | 1.3 | 1.55 | 1.7 |
| 23 | 20.3 | 6.6 | 9.0 | 4.55 | 3.35 | 2.25 | 1.55 | 1.3 | 1.25 | 1.3 | 1.55 | 1.55 |
| 24 | 15.55 | 6.0 | 9.8 | 4.4 | 3.3 | 2.2 | 1.5 | 1.3 | 1.25 | 1.3 | 1.55 | 1.55 |
| 25 | 15.45 | 5.7 | 8.45 | 4.4 | 3.2 | 2.25 | 1.5 | 1.25 | 1.25 | 1.3 | 1.55 | 1.55 |
| 26 | 12.75 | 5.45 | 9.0 | 4.4 | 3.2 | 2.2 | 1.45 | 1.25 | 1.25 | 1.3 | 1.55 | 1.55 |
| 27 | 9.8 | 5.3 | 8.9 | 4.3 | 3.2 | 2.1 | 1.45 | 1.25 | 1.25 | 1.3 | 1.6 | 1.7 |
| 28 | 8.95 | 5.0 | 8.2 | 4.15 | 3.2 | 2.0 | 1.45 | 1.25 | 1.3 | 1.3 | 1.7 | 1.7 |
| 29 | 7.5 | ..... | 15.5 | 4.05 | 3.2 | 2.0 | 1.45 | 1.25 | 1.3 | 1.3 | 1.8 | 1.9 |
| 30 | 6.85 | ..... | 9.85 | 4.0 | 3.15 | 1.95 | 1.45 | 1.25 | 1.3 | 1.3 | 1.95 | 1.8 |
| 31 | 6.55 | ..... | 8.7 | ..... | 3.05 | ..... | 1.45 | 1.25 | ..... | 1.3 | ..... | 1.9 |

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*Station rating table for Sacramento River near Red Bluff, Cal., from January 1, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.00 | 4,450 | 3.10 | 10,380 | 5.40 | 18,700 | 9.60 | 37,180 |
| 1.10 | 4,690 | 3.20 | 10,710 | 5.60 | 19,500 | 9.80 | 38,140 |
| 1.20 | 4,930 | 3.30 | 11,040 | 5.80 | 20,300 | 10.00 | 39,100 |
| 1.30 | 5,170 | 3.40 | 11,370 | 6.00 | 21,100 | 10.50 | 41,600 |
| 1.40 | 5,410 | 3.50 | 11,700 | 6.20 | 21,940 | 11.00 | 44,200 |
| 1.50 | 5,650 | 3.60 | 12,040 | 6.40 | 22,780 | 11.50 | 46,900 |
| 1.60 | 5,920 | 3.70 | 12,380 | 6.60 | 23,620 | 12.00 | 49,700 |
| 1.70 | 6,190 | 3.80 | 12,720 | 6.80 | 24,460 | 12.50 | 52,600 |
| 1.80 | 6,460 | 3.90 | 13,060 | 7.00 | 25,300 | 13.00 | 55,600 |
| 1.90 | 6,730 | 4.00 | 13,400 | 7.20 | 26,180 | 13.50 | 58,600 |
| 2.00 | 7,000 | 4.10 | 13,760 | 7.40 | 27,060 | 14.00 | 61,700 |
| 2.10 | 7,300 | 4.20 | 14,120 | 7.60 | 27,940 | 14.50 | 64,900 |
| 2.20 | 7,600 | 4.30 | 14,480 | 7.80 | 28,820 | 15.00 | 68,200 |
| 2.30 | 7,900 | 4.40 | 14,840 | 8.00 | 29,700 | 16.00 | 75,100 |
| 2.40 | 8,200 | 4.50 | 15,200 | 8.20 | 30,620 | 17.00 | 82,200 |
| 2.50 | 8,500 | 4.60 | 15,580 | 8.40 | 31,540 | 18.00 | 89,700 |
| 2.60 | 8,810 | 4.70 | 15,960 | 8.60 | 32,460 | 19.00 | 97,600 |
| 2.70 | 9,120 | 4.80 | 16,340 | 8.80 | 33,380 | 20.00 | 105,900 |
| 2.80 | 9,430 | 4.90 | 16,720 | 9.00 | 34,300 | | |
| 2.90 | 9,740 | 5.00 | 17,100 | 9.20 | 35,260 | | |
| 3.00 | 10,050 | 5.20 | 17,900 | 9.40 | 36,220 | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1902–1905. It is fairly well defined.

*Estimated monthly discharge of Sacramento River near Red Bluff, Cal., for 1905.*

[Drainage area, 9,295 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 108,500 | 10,380 | 31,830 | 1,957,000 | 3.42 | 3.94 |
| February | 74,050 | 15,200 | 26,800 | 1,488,000 | 2.88 | 3.00 |
| March | 71,600 | 13,580 | 30,920 | 1,901,000 | 3.33 | 3.84 |
| April | 29,930 | 13,400 | 18,680 | 1,112,000 | 2.01 | 2.24 |
| May | 19,100 | 10,220 | 12,750 | 784,000 | 1.37 | 1.58 |
| June | 10,050 | 6,865 | 8,623 | 513,100 | .928 | 1.04 |
| July | 6,865 | 5,530 | 6,075 | 373,500 | .654 | .754 |
| August | 5,530 | 5,050 | 5,251 | 322,900 | .565 | .651 |
| September | 5,170 | 5,050 | 5,062 | 301,200 | .545 | .608 |
| October | 5,170 | 5,050 | 5,155 | 317,000 | .555 | .640 |
| November | 6,865 | 5,170 | 5,616 | 334,200 | .604 | .674 |
| December | 7,300 | 5,785 | 6,100 | 375,100 | .656 | .756 |
| The year | 108,500 | 5,050 | 13,570 | 9,779,000 | 1.46 | 19.72 |

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## SACRAMENTO RIVER AT SACRAMENTO, CAL.

The following gage heights were observed at this station during 1905:

*Daily gage height, in feet, of Sacramento River at Sacramento, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. |
|---|---|---|---|---|---|---|---|
| 1 | 18.5 | 20.9 | 19.7 | 21.8 | 19.6 | 17.4 | 11.4 |
| 2 | 18.0 | 21.6 | 19.7 | 21.8 | 19.8 | 17.3 | 11.2 |
| 3 | 17.7 | 21.8 | 19.6 | 21.7 | 19.6 | 17.2 | 11.0 |
| 4 | 18.1 | 21.8 | 19.5 | 21.7 | 19.6 | 17.0 | 10.9 |
| 5 | 18.4 | 21.9 | 19.5 | 21.6 | 19.0 | 16.9 | 10.8 |
| 6 | 18.4 | 22.0 | 19.4 | 21.5 | 18.9 | 16.4 | 10.7 |
| 7 | 18.2 | 21.9 | 19.3 | 21.5 | 19.0 | 16.3 | 10.6 |
| 8 | 18.1 | 21.9 | 19.0 | 21.5 | 19.0 | 16.2 | 10.5 |
| 9 | 18.0 | 21.8 | 18.8 | 21.6 | 19.0 | 16.1 | 10.4 |
| 10 | 17.8 | 21.8 | 18.7 | 21.6 | 19.3 | 16.0 | 10.3 |
| 11 | 17.5 | 21.6 | 18.2 | 21.2 | 18.9 | 16.0 | 10.0 |
| 12 | 17.1 | 21.4 | 18.1 | 21.0 | 18.8 | 16.0 | 9.9 |
| 13 | 16.7 | 21.2 | 18.0 | 20.9 | 18.5 | 15.9 | 9.8 |
| 14 | 16.7 | 20.9 | 18.9 | 20.8 | 18.5 | 15.8 | 9.7 |
| 15 | 17.4 | 20.8 | 18.9 | 20.7 | 18.6 | 15.4 | 9.7 |
| 16 | 18.0 | 20.5 | 19.0 | 20.6 | 18.8 | 15.1 | 9.6 |
| 17 | 18.2 | 20.4 | 19.2 | 20.6 | 19.3 | 15.0 | 9.5 |
| 18 | 18.5 | 20.4 | 19.4 | 20.2 | 18.9 | 14.7 | 9.4 |
| 19 | 18.8 | 20.4 | 20.1 | 20.4 | 18.9 | 14.5 | 9.3 |
| 20 | 19.0 | 20.4 | 21.0 | 20.3 | 18.9 | 14.0 | 9.2 |
| 21 | 19.0 | 20.4 | 20.8 | 20.2 | 18.8 | 13.8 | 9.1 |
| 22 | 20.0 | 20.2 | 21.1 | 20.0 | 18.8 | 13.6 | 9.0 |
| 23 | 20.5 | 20.1 | 21.0 | 19.9 | 18.6 | 13.3 | 8.9 |
| 24 | 20.2 | 20.0 | 21.2 | 19.8 | 18.5 | 13.0 | 8.8 |
| 25 | 20.4 | 20.0 | 21.2 | 19.7 | 18.0 | 12.7 | 8.7 |
| 26 | 20.5 | 20.0 | 21.3 | 19.8 | 17.9 | 12.4 | 8.6 |
| 27 | 20.7 | 20.0 | 21.7 | 20.1 | 18.0 | 12.0 | 8.4 |
| 28 | 20.8 | 19.9 | 21.6 | 20.0 | 17.9 | 11.9 | 8.2 |
| 29 | 20.8 | ..... | 21.8 | 19.9 | 17.8 | 11.8 | 8.2 |
| 30 | 20.9 | ..... | 21.8 | 19.8 | 17.7 | 11.6 | ..... |
| 31 | 20.9 | ..... | 21.9 | ..... | 17.5 | ..... | ..... |

## MISCELLANEOUS MEASUREMENTS IN SACRAMENTO RIVER DRAINAGE BASIN.

*Sacramento River at Baird Station, on Southern Pacific Railway, Gregory post-office, Cal.*—A measurement of this stream was made August 28, 1905, from wagon bridge by W. B. Clapp.

Width, 116 feet; area, 308 square feet; mean velocity, 1.14 feet per second; discharge, 352 second-feet.

*Clear Creek near Stella post-office, Cal.*—A measurement was made of this stream August 26, 1905, 500 feet above mouth of Brandy Creek by W. B. Clapp.

Width, 28 feet; area, 31 square feet; mean velocity, 1.26 feet per second; discharge, 39 second-feet.

*North Fork Cottonwood Creek near Gas Point, Cal.*—A measurement of this stream was made August 28, 1905, 40 feet below the highway bridge above the junction of the North and Middle forks by C. H. Lee. Several diversions are made above the point of measurement; their total discharge is reported to be about 8 second-feet.

Width, 15.5 feet; area, 9.0 square feet; mean velocity, 0.66 foot per second; discharge, 5.9 second-feet.

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*Middle Fork Cottonwood Creek near Gas Point, Cal.*—A measurement of this stream was made August 28, 1905, 300 feet above its junction with the North Fork by C. H. Lee. Three small diversions are made above the point of measurement.

Width, 35 feet; area, 11.3 square feet; mean velocity, 0.81 foot per second; discharge, 9.1 second-feet.

*Pit River near Copper City, Cal.*—This stream is the largest tributary of the Sacramento River, joining it about 11 miles north of Redding, Cal. It has a well-sustained summer flow. A measurement of this stream was made August 25, 1905, by C. H. Lee from the downstream side of the Delamar Mining Company's toll bridge above the mouth of Squaw Creek.

Width, 135 feet; area, 465 square feet; mean velocity, 6.68 feet per second; discharge, 3,107 second-feet.

*Squaw Creek near Copper City, Cal.*—A measurement of this stream was made 500 feet below bridge near Copper City by C. H. Lee on August 26, 1905.

Width, 39 feet; area, 95 square feet; mean velocity, 0.21 foot per second; discharge, 20 second-feet.

*Cow Creek (above Clover Creek) at Millville, Cal.*—A measurement of this stream was made August 26, 1905, at the highway bridge south of Millville by C. H. Lee.

Width, 39.2 feet; area, 35 square feet; mean velocity, 1.75 feet per second; discharge, 61 second-feet.

*Clover Creek at Millville, Cal.*—A measurement of this stream was made August 26, 1905, about 500 feet below the highway bridge above its junction with Cow Creek by C. H. Lee.

Width, 15 feet; area, 7.8 square feet; mean velocity, 0.40 foot per second; discharge, 3.1 second-feet.

*Clover Creek ditch.*—A measurement of this ditch was made on August 27, 1905, in flume at its heading, 3 miles above Millville by C. H. Lee.

Width, 2.15 feet; area, 1.8 square feet; mean velocity, 1.33 feet per second; discharge, 2.4 second-feet. This water is diverted from Clover Creek.

*Little Cow Creek near Palocedro, Cal.*—A measurement of this stream was made on August 27, 1905, 800 feet downstream from the highway bridge east of Palocedro by C. H. Lee. There are several small diversions from this stream above this point.

Width, 11.2 feet; area, 9.0 square feet; mean velocity, 0.50 foot per second; discharge, 4.5 second-feet.

*Cow Creek near Palocedro, Cal.*—A measurement of this stream was made August 27, 1905, 150 feet below its junction with Little Cow Creek by C. H. Lee.

Width, 41.5 feet; area, 58 square feet; mean velocity, 1.05 feet per second; discharge, 61 second-feet.

*Battle Creek near Balls Ferry, Cal.*—This stream is an important tributary of the Sacramento River. A measurement was made August 29, 1905, at a point about 2 miles above the wagon bridge on main road from Red Bluff to Balls Ferry by C. H. Lee.

Width, 88 feet; area, 171 square feet; mean velocity, 1.92 feet per second; discharge, 329 second-feet.

*Mill ditch near Balls Ferry, Cal.*—This ditch heads in Battle Creek 1½ miles above the wagon bridge on the main road from Red Bluff to Balls Ferry. A measurement was made August 29, 1905, 1½ miles below head of ditch, by C. H. Lee.

Width, 22 feet; area, 19.3 square feet; mean velocity, 1.33 feet per second; discharge, 26 second-feet.

*Antelope Creek near Red Bluff, Cal.*—A measurement of this stream was made August 31, 1905, 600 feet above the Antelope Creek and Red Bluff Water Company's dam, about 8 miles east of Red Bluff, by C. H. Lee.

Width, 36 feet; area, 83 square feet; mean velocity, 0.54 foot per second; discharge, 45 second-feet.

*Mill Creek near Tehama, Cal.*—A measurement of this stream was made September 1, 1905, 300 feet above the head-gate of the Los Molinas ditch and about 6 miles east of Tehama, by C. H. Lee.

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Width, 40.2 feet; area, 91 square feet; mean velocity, 1.34 feet per second; discharge, 122 second-feet.

*Millrace canal near Tehama, Cal.*—This canal diverts water from Mill Creek about 1½ miles above its junction with Sacramento River. A measurement was made in flume at head of canal September 1, 1905, by C. H. Lee.

Width, 11.8 feet; area, 40 square feet; mean velocity, 2.25 feet per second; discharge, 90 second-feet.

*Deer Creek near Vina, Cal.*—A measurement of this stream was made September 1, 1905, from the downstream side of the bridge at upper main road crossing, about 4 miles from Vina, by C. H. Lee. Two or three small ditches divert water from creek above this point of measurement.

Width, 57.7 feet; area, 77 square feet; mean velocity, 1.08 feet per second; discharge, 83 second-feet.

*Valley Counties Power Company's canal near Centerville, Cal.*—This canal diverts water from Butte Creek. A measurement was made May 19 in flume at town of Centerville.

Width, 6 feet; area, 13.2 square feet; mean velocity, 1.74 feet per second; discharge, 23 second-feet.

## PIT RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Pit River has its source in the Warner Mountains in the extreme northeast part of California. It flows in a southwesterly direction, discharging its waters into Sacramento River a few miles above Redding, Cal. It has numerous tributaries, the larger of which have their source in large springs, which discharge from crevices in the lava formation. About 50 per cent of the area of this drainage basin is barren of timber and composed, principally, of lava with a light soil covering, being used extensively for pasturage and the raising of stock. There are numerous small valleys with light grades, which hold the water throughout the summer months principally in the state of swamps. These areas are used, mainly, as meadow land and for the raising of stock feed. Pit River does not discharge in any great volume until it reaches a point near Fall River Mills, which lies about midway between the point where the Pit River enters the Sacramento and its source. Fall River, which is the principal tributary of the Pit from the north, receives its water supply from large perennial springs which discharge 1,500 second-feet. Hat Creek and Burney Creek are also large tributaries from the south and drain the northern slope of Lassen Peak. Their principal sources are also from large perennial springs in the lava formation.

West Valley Creek is a tributary of South Fork of Pit River. Ash Creek flows into Clear Creek, through which it enters Pit River from the south. There is considerable timber scattered throughout this drainage basin, the principal growth lying in the southern portion of the basin and also in that section lying north of Pit River and between Fall River and the upper Sacramento. There are numerous reservoir sites on the upper reaches of this stream, all of which have been or are being surveyed. Several gaging stations are maintained on Pit River and tributaries at points where surveys have been made for the construction of storage reservoirs. The rainfall throughout this basin is very unevenly distributed, ranging from 10 inches in the eastern portion to 50 to 75 inches in the western and northwestern portion. About 50 per cent of the precipitation falls in the form of snow, but does not remain any length of time except on the higher elevation of Mount Shasta and Lassen Peak.

McCloud River drains the southeastern slope of Mount Shasta. Its drainage area is comparatively small, covering 676 square miles. It is long and narrow, extending from north to south. There are few tributaries. Its main water supply comes from Mount Shasta, on which the snow remains during the entire year. It is also fed by numerous large springs scattered throughout the drainage basin. The precipitation is very heavy and is principally in the form of rain, except on the higher elevations of Mount Shasta. The discharge of this stream seldom falls below 1,200 second-feet. It discharges into the Pit River a few miles above the junction of the Pit with the Sacramento. The entire basin is well timbered.

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### PIT RIVER NEAR CANBY, CAL.

This station was established December 26, 1903, by H. E. Green and J. S. Evans. It is located at the wagon bridge, 3½ miles southwest of Canby, Cal.

The channel is straight for 150 feet above and 200 feet below the station. The current is moderate at all stages. The banks are high and are subject to overflow. The channel is rocky and is not subject to much change.

Discharge measurements are made from the bridge. The initial point for soundings is a nail in the railing post at the end of the bridge on the left bank.

The gage is a vertical plank securely fastened to the first bridge pier from the left bank of the stream. During 1905 the gage was read twice each day by Ernest M. Hess. The bench mark is a painted point on a large bowlder at the bend of the wagon road near the south end of the bridge. Elevation, 24.90 feet above the datum of the gage.

A description of this station, with gage height and discharge data, is contained in Water-Supply Paper No. 134, United States Geological Survey.

*Discharge measurements of Pit River near Canby, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 5 | J. Y. Toler | 99 | 187 | 2.55 | 4.20 | 476 |
| January 9 | do | 87 | 127 | 1.70 | 3.70 | 216 |
| January 20 | do | 99 | 186 | 2.53 | 4.18 | 470 |
| January 26 | do | 117 | 228 | 2.96 | 4.50 | 675 |
| February 7 | do | 116 | 220 | 2.91 | 4.40 | 641 |
| February 13 | do | 87 | 131 | 1.91 | 3.70 | 250 |
| February 22 | do | 119 | 235 | 3.03 | 4.60 | 712 |
| February 27 | do | 93 | 147 | 2.11 | 3.90 | 309 |
| March 7 | do | 87 | 128 | 1.86 | 3.65 | 238 |
| March 9 | do | 87 | 127 | 1.83 | 3.65 | 233 |
| March 14 | do | 87 | 135 | 1.80 | 3.70 | 243 |
| March 22 | do | 109 | 227 | 2.90 | 4.60 | 659 |
| March 26 | do | 109 | 230 | 2.93 | 4.65 | 674 |
| April 4 | do | 138 | 292 | 3.33 | 5.00 | 971 |
| April 5 | do | 138 | 289 | 3.30 | 5.00 | 955 |
| April 10 | do | 114 | 206 | 2.81 | 4.40 | 579 |
| April 16 | do | 93 | 146 | 2.27 | 4.00 | 331 |
| April 19 | do | 93 | 136 | 2.07 | 3.90 | 282 |
| May 1 | do | 63 | 83 | 1.08 | 3.30 | 90 |
| May 2 | do | 63 | 83 | 1.10 | 3.30 | 91 |
| May 5 | do | 61 | 54 | .57 | 2.90 | 31 |
| May 16 | do | 90 | 120 | 1.85 | 3.70 | 222 |
| May 20 | do | 90 | 115 | 1.84 | 3.70 | 212 |
| June 9 | do | 87 | 123 | 1.64 | 3.60 | 201 |
| July 17 | do | 52 | 40 | .60 | 2.90 | 24 |
| July 22 | do | 50 | 37 | .62 | 2.85 | 23 |
| August 8 | do | 60 | 39 | .37 | 2.80 | 14.5 |
| August 10 | do | 60 | 37 | .38 | 2.75 | 14.1 |
| August 21 | do | 9 | 2.9 | 1.27 | 2.50 | 3.7 |
| August 28 | do | 7 | 1.8 | 1.17 | 2.45 | 2.1 |
| August 31 | do | 7 | 2.0 | 1.15 | 2.45 | 2.3 |
| September 9 | do | 8 | 2.6 | 1.19 | 2.50 | 3.1 |
| September 19 | do | 9 | 3.4 | 1.68 | 2.60 | 5.7 |
| October 6 | do | 35 | 21 | 1.00 | 2.80 | 21 |
| October 19 | do | 55 | 57 | .91 | 3.10 | 52 |
| October 25 | do | 58 | 58 | .86 | 3.20 | 50 |
| October 28 | do | 58 | 61 | .90 | 3.20 | 55 |
| November 7 | do | 60 | 67 | 1.19 | 3.30 | 80 |
| November 11 | do | 60 | 70 | 1.19 | 3.30 | 83 |

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*Daily gage height, in feet, of Pit River near Canby, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.55 | 4.6 | 3.8 | 5.5 | 3.4 | 3.6 | 3.3 | 2.9 | 2.5 | 2.8 | 3.2 | 3.5 |
| 2 | 4.4 | 5.05 | 3.8 | 5.6 | 3.4 | 3.7 | 3.25 | 2.9 | 2.5 | 2.8 | 3.25 | 3.5 |
| 3 | 4.1 | 5.25 | 3.75 | 5.5 | 3.3 | 3.7 | 3.25 | 2.9 | 2.5 | 2.8 | 3.25 | 3.5 |
| 4 | 4.0 | 5.65 | 3.7 | 5.4 | 3.0 | 3.7 | 3.25 | 2.9 | 2.5 | 2.8 | 3.3 | 3.5 |
| 5 | 3.9 | 4.85 | 3.7 | 5.5 | 3.0 | 3.7 | 3.25 | 2.9 | 2.5 | 2.8 | 3.3 | 3.5 |
| 6 | 3.8 | 4.65 | 3.7 | 4.8 | 3.0 | 3.5 | 3.25 | 2.5 | 2.5 | 2.8 | 3.3 | 3.5 |
| 7 | 3.8 | 4.25 | 3.65 | 4.8 | 3.6 | 3.6 | 3.2 | 2.5 | 2.5 | 2.8 | 3.3 | 3.5 |
| 8 | 3.8 | 4.1 | 3.65 | 4.7 | 3.6 | 3.7 | 3.2 | 2.5 | 2.5 | 2.8 | 3.3 | 3.5 |
| 9 | 3.7 | 4.05 | 3.65 | 4.5 | 3.3 | 3.65 | 3.2 | 2.5 | 2.5 | 3.05 | 3.3 | 3.5 |
| 10 | 3.6 | 4.0 | 3.65 | 4.3 | 3.15 | 3.65 | 3.2 | 2.5 | 2.5 | 3.05 | 3.3 | 3.4 |
| 11 | 3.55 | 3.9 | 3.65 | 4.2 | 3.2 | 3.6 | 3.2 | 2.5 | 2.5 | 3.05 | 3.3 | 3.4 |
| 12 | 3.45 | 3.7 | 3.7 | 4.1 | 3.2 | 3.6 | 3.2 | 2.5 | 2.5 | 3.05 | 3.3 | 3.35 |
| 13 | 3.5 | 3.7 | 3.7 | 4.1 | 3.2 | 3.6 | 3.2 | 2.5 | 2.5 | 3.05 | 3.3 | 3.3 |
| 14 | 3.7 | 3.75 | 3.7 | 4.0 | 3.6 | 3.5 | 3.2 | 2.5 | 2.5 | 3.05 | 3.3 | 3.3 |
| 15 | 3.95 | 3.7 | 3.7 | 4.0 | 3.8 | 3.5 | 3.2 | 2.5 | 2.5 | 3.1 | 3.3 | 3.3 |
| 16 | 4.25 | 3.65 | 3.8 | 4.0 | 3.8 | 3.4 | 3.2 | 2.5 | 2.5 | 3.1 | 3.25 | 3.3 |
| 17 | 4.3 | 3.75 | 4.1 | 4.0 | 3.8 | 3.4 | 3.2 | 2.5 | 2.5 | 3.15 | 3.25 | 3.3 |
| 18 | 4.3 | 3.8 | 4.35 | 4.0 | 3.8 | 3.4 | 3.2 | 2.5 | 2.5 | 3.15 | 3.25 | 3.3 |
| 19 | 4.3 | 4.2 | 4.4 | 4.0 | 3.8 | 3.4 | 3.2 | 2.5 | 2.6 | 3.2 | 3.25 | 3.35 |
| 20 | 4.2 | 4.95 | 4.5 | 3.95 | 3.8 | 3.4 | 3.2 | 2.4 | 2.6 | 3.2 | 3.3 | 3.4 |
| 21 | 4.1 | 4.8 | 4.95 | 3.85 | 3.75 | 3.4 | 3.2 | 2.4 | 2.6 | 3.2 | 3.3 | 3.4 |
| 22 | 4.35 | 4.6 | 4.8 | 3.8 | 3.7 | 3.4 | 3.2 | 2.4 | 2.6 | 3.2 | 3.3 | 3.4 |
| 23 | 4.5 | 4.3 | 4.45 | 3.3 | 3.65 | 3.4 | 3.1 | 2.4 | 2.6 | 3.2 | 3.35 | 3.4 |
| 24 | 5.0 | 4.2 | 4.5 | 3.3 | 3.8 | 3.4 | 3.1 | 2.4 | 2.6 | 3.2 | 3.35 | 3.4 |
| 25 | 5.35 | 4.1 | 4.6 | 3.3 | 3.7 | 3.4 | 3.1 | 2.4 | 2.6 | 3.2 | 3.4 | 3.4 |
| 26 | 4.6 | 4.0 | 4.7 | 3.3 | 3.6 | 3.4 | 3.1 | 2.4 | 2.6 | 3.2 | 3.4 | 3.4 |
| 27 | 4.2 | 4.0 | 4.8 | 3.4 | 3.5 | 3.3 | 3.1 | 2.5 | 2.7 | 3.2 | 3.4 | 3.4 |
| 28 | 4.05 | 3.9 | 4.85 | 3.4 | 3.5 | 3.3 | 3.1 | 2.5 | 2.8 | 3.2 | 3.4 | 3.4 |
| 29 | 4.0 | ..... | 4.85 | 3.5 | 3.5 | 3.3 | 3.1 | 2.5 | 2.8 | 3.2 | 3.45 | 3.4 |
| 30 | 4.0 | ..... | 4.8 | 3.4 | 3.6 | 3.3 | 3.1 | 2.5 | 2.8 | 3.2 | 3.5 | 3.4 |
| 31 | 4.15 | ..... | 5.0 | ..... | 3.6 | ..... | 3.1 | 2.5 | ..... | 3.2 | ..... | 3.4 |

*Station rating table for Pit River near Canby, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.40 | 1.5 | 3.30 | 87 | 4.20 | 475 | 5.10 | 1,028 |
| 2.50 | 3.5 | 3.40 | 115 | 4.30 | 533 | 5.20 | 1,091 |
| 2.60 | 6 | 3.50 | 148 | 4.40 | 593 | 5.30 | 1,154 |
| 2.70 | 10 | 3.60 | 186 | 4.50 | 655 | 5.40 | 1,217 |
| 2.80 | 16 | 3.70 | 226 | 4.60 | 717 | 5.50 | 1,280 |
| 2.90 | 24 | 3.80 | 269 | 4.70 | 779 | 5.60 | 1,343 |
| 3.00 | 34 | 3.90 | 316 | 4.80 | 841 | | |
| 3.10 | 47 | 4.00 | 366 | 4.90 | 903 | | |
| 3.20 | 64 | 4.10 | 419 | 5.00 | 965 | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on thirty-nine discharge measurements made during 1905. It is well defined between gage heights 2.4 feet and 5 feet.

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*Estimated monthly discharge of Pit River near Canby, Cal., for 1905.*

[Drainage area, 1,500 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 1,186 | 132 | 443 | 27,240 | 0.295 | 0.340 |
| February | 1,374 | 206 | 533 | 29,600 | .355 | .370 |
| March | 965 | 206 | 479 | 29,450 | .319 | .368 |
| April | 1,343 | 87 | 510 | 30,350 | .340 | .379 |
| May | 269 | 34 | 165 | 10,140 | .110 | .127 |
| June | 226 | 87 | 151 | 8,985 | .101 | .113 |
| July | 87 | 47 | 61.7 | 3,794 | .041 | .047 |
| August | 24 | 1.5 | 6.4 | 394 | .0043 | .0050 |
| September | 16 | 3.5 | 5.6 | 333 | .0037 | .0041 |
| October | 64 | 16 | 45.4 | 2,792 | .030 | .035 |
| November | 148 | 64 | 92.2 | 5,486 | .061 | .068 |
| December | 148 | 87 | 118 | 7,256 | .079 | .091 |
| The year | 1,374 | 1.5 | 218 | 155,800 | .145 | 1.95 |

### PIT RIVER NEAR BIEBER, CAL.

This station was established January 22, 1904, by J. S. Evans and William Busch. It is located 12 miles below Bieber, Cal., near Muck Valley.

The channel is straight for 200 feet above and 300 feet below the station. The current is very sluggish at low-water stage. The banks are high and not subject to overflow. The channel is very rocky and rough, but is not subject to change.

Discharge measurements are made from a cable and car. The initial point for soundings is the foot of the platform at end of the cable on the right bank of the stream.

The gage is a heavy wooden rod fastened to a large bowlder on the right bank of the stream. During 1905 the gage was read once each day by F. H. Holabird. The bench mark is on a large bowlder on the right bank 50 feet east of the pine tree to which the cable is fastened; elevation 12.00 feet above the datum of the gage.

A description of this station and gage height and discharge data are contained in Water-Supply Paper No. 134, United States Geological Survey.

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*Discharge measurements of Pit River near Bieber, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 8 | J. Y. Toler | 104 | 343 | 0.99 | 3.70 | 340 |
| January 22 | do | 210 | 729 | 1.96 | 5.25 | 1,430 |
| January 23 | do | 218 | 915 | 2.46 | 6.00 | 2,254 |
| Do | do | 217 | 889 | 2.50 | 5.94 | 2,220 |
| February 9 | do | 204 | 630 | 1.68 | 4.80 | 1,060 |
| February 24 | do | 208 | 673 | 1.93 | 5.08 | 1,296 |
| March 11 | do | 144 | 389 | .97 | 3.70 | 378 |
| March 24 | do | 212 | 743 | 2.22 | 5.40 | 1,650 |
| March 23 | do | 213 | 767 | 2.11 | 5.51 | 1,620 |
| April 7 | do | 210 | 739 | 2.02 | 5.30 | 1,492 |
| April 6 | do | 212 | 757 | 2.18 | 5.40 | 1,648 |
| April 17 | do | 199 | 504 | 1.32 | 4.30 | 665 |
| May 3 | do | 126 | 232 | .61 | 2.88 | 141 |
| May 18 | do | 134 | 309 | .79 | 3.50 | 244 |
| June 12 | do | 126 | 215 | .51 | 2.80 | 110 |
| July 7 | do | 75 | 143 | .24 | 2.30 | 34 |
| July 19 | do | 79 | 144 | .29 | 2.40 | 42 |
| August 9 | do | 58 | 105 | .22 | 1.85 | 23 |
| August 18 | do | 34 | 18.8 | 1.02 | 1.80 | 19.1 |
| August 29 | do | 30 | 12.6 | .78 | 1.70 | 9.9 |
| September 10 | do | 6 | 2.4 | .46 | 1.40 | 1.1 |
| September 20 | do | 7 | 2.0 | .60 | 1.40 | 1.2 |
| October 7 | do | 6 | 2.8 | .61 | 1.50 | 1.7 |
| October 17 | do | 31 | 12.7 | .83 | 1.70 | 10.5 |
| October 26 | do | 45 | 22.5 | 1.80 | 2.20 | 41 |
| November 8 | do | 80 | 168 | .42 | 2.60 | 71 |



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*Daily gage height, in feet, of Pit River near Bieber, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.8 | 5.4 | 4.6 | 6.2 | 3.0 | 3.2 | 2.5 | 2.1 | 1.5 | a1.5 | a2.3 | a2.4 |
| 2 | 5.0 | 5.5 | 4.5 | 6.3 | 3.0 | 3.2 | 2.45 | 2.1 | 1.5 | a1.5 | a2.4 | a2.4 |
| 3 | 4.9 | 5.3 | 4.3 | 6.15 | 2.9 | 3.1 | 2.4 | 1.9 | 1.5 | a1.5 | a2.4 | a2.4 |
| 4 | 4.5 | 5.0 | 4.0 | 5.9 | 2.9 | 3.1 | 2.4 | 1.8 | 1.4 | a1.5 | a2.5 | a2.4 |
| 5 | 4.2 | 4.8 | 4.0 | 5.7 | 2.9 | 3.1 | 2.4 | 1.8 | 1.4 | a1.5 | a2.5 | a2.4 |
| 6 | 3.9 | 4.6 | 4.0 | 5.4 | 3.0 | 3.0 | 2.3 | 1.8 | 1.4 | a1.5 | a2.5 | a2.4 |
| 7 | 3.7 | 6.0 | 3.9 | 5.2 | 3.0 | 3.0 | 2.3 | 1.75 | 1.4 | 1.5 | a2.5 | a2.4 |
| 8 | 3.7 | 5.5 | 3.9 | 5.1 | 3.0 | 2.9 | 2.3 | 1.75 | 1.35 | a1.5 | 2.6 | a2.4 |
| 9 | 3.5 | 4.8 | 3.8 | 5.0 | 2.9 | 2.9 | 2.4 | 1.85 | 1.35 | a1.5 | a2.6 | a2.4 |
| 10 | 3.4 | 4.6 | 3.7 | 4.9 | 2.9 | 2.8 | 2.35 | 1.8 | 1.4 | a1.5 | a2.6 | a2.4 |
| 11 | 3.4 | 4.3 | 3.7 | 4.7 | 2.8 | 2.8 | 2.45 | 1.8 | 1.4 | a1.5 | a2.6 | a2.4 |
| 12 | 3.3 | 3.9 | 3.7 | 4.6 | 2.8 | 2.8 | 2.45 | 1.5 | 1.4 | a1.6 | a2.6 | a2.3 |
| 13 | 3.4 | 3.7 | 3.7 | 4.4 | 2.8 | 2.8 | 2.4 | 1.5 | 1.4 | a1.6 | a2.6 | a2.3 |
| 14 | 3.4 | 3.7 | 3.8 | 4.3 | 2.8 | 2.7 | 2.4 | 1.5 | a1.4 | a1.6 | a2.6 | a2.3 |
| 15 | 3.6 | 3.9 | 3.8 | 4.2 | 2.8 | 2.7 | 2.7 | 1.5 | a1.4 | a1.6 | a2.7 | a2.3 |
| 16 | 3.9 | 4.0 | 4.0 | 4.3 | 3.0 | 2.7 | 2.7 | 1.7 | a1.4 | a1.6 | a2.7 | a2.3 |
| 17 | 4.95 | 4.1 | 4.0 | 4.3 | 3.4 | 2.7 | 2.7 | 1.7 | a1.4 | 1.7 | a2.7 | a2.3 |
| 18 | 5.1 | 4.3 | 5.0 | 4.3 | 3.5 | 2.7 | 2.3 | 1.8 | a1.4 | 2.0 | a2.7 | a2.3 |
| 19 | 5.0 | 4.6 | 5.4 | 4.2 | 3.5 | 2.5 | 2.4 | 1.8 | a1.4 | 2.0 | a2.7 | a2.3 |
| 20 | 5.0 | 4.8 | 5.5 | 4.0 | 3.4 | 2.5 | 2.4 | 1.7 | a1.4 | 2.0 | a2.7 | a2.3 |
| 21 | 5.0 | 5.0 | 5.5 | 4.0 | 3.4 | 2.5 | 2.3 | 1.7 | a1.4 | 2.0 | a2.7 | 3.3 |
| 22 | 5.25 | 5.8 | 5.8 | 3.9 | 3.2 | 2.4 | 2.2 | 1.5 | a1.4 | 2.0 | a2.7 | 3.3 |
| 23 | 5.95 | 5.2 | 5.55 | 3.9 | 3.2 | 2.4 | 2.2 | 1.5 | a1.4 | 2.0 | a2.6 | 2.2 |
| 24 | 6.5 | 5.05 | 5.45 | 3.7 | 3.2 | 2.4 | 2.6 | 1.5 | a1.4 | a2.0 | a2.6 | 2.2 |
| 25 | 6.0 | 5.0 | 5.4 | 3.6 | 3.1 | 2.3 | 2.4 | 1.5 | a1.4 | a2.0 | a2.6 | 2.2 |
| 26 | 5.8 | 5.0 | 5.7 | 3.4 | 3.1 | 2.3 | 2.1 | 1.5 | a1.4 | 2.2 | a2.6 | 2.2 |
| 27 | 5.5 | 4.8 | 5.9 | 3.1 | 3.0 | 2.3 | 2.1 | 1.7 | a1.4 | a2.2 | a2.6 | 2.2 |
| 28 | 5.0 | 4.8 | 5.8 | 3.1 | 3.1 | 2.7 | 2.1 | 1.7 | 1.5 | a2.2 | a2.6 | 2.2 |
| 29 | 4.8 | ..... | 5.8 | 3.1 | 3.2 | 2.7 | 2.2 | 1.7 | 1.5 | a2.2 | a2.6 | 2.2 |
| 30 | 5.1 | ..... | 5.8 | 3.0 | 3.3 | 2.7 | 2.2 | 1.5 | a1.5 | a2.3 | a2.5 | 2.2 |
| 31 | 5.4 | ..... | 6.0 | ..... | 3.3 | ..... | 2.25 | 1.5 | ..... | a2.3 | ..... | 2.2 |

a Estimated.

NOTE.—River frozen over December 23–31.

*Station rating table for Pit River near Bieber, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.30 | 0.5 | 2.50 | 64 | 3.70 | 349 | 4.90 | 1,130 |
| 1.40 | 1.0 | 2.60 | 77 | 3.80 | 396 | 5.00 | 1,215 |
| 1.50 | 2.2 | 2.70 | 92 | 3.90 | 448 | 5.20 | 1,400 |
| 1.60 | 5.8 | 2.80 | 109 | 4.00 | 505 | 5.40 | 1,595 |
| 1.70 | 9.6 | 2.90 | 127 | 4.10 | 565 | 5.60 | 1,810 |
| 1.80 | 13.6 | 3.00 | 147 | 4.20 | 630 | 5.80 | 2,035 |
| 1.90 | 18 | 3.10 | 168 | 4.30 | 695 | 6.00 | 2,270 |
| 2.00 | 23 | 3.20 | 190 | 4.40 | 760 | 6.20 | 2,525 |
| 2.10 | 29 | 3.30 | 213 | 4.50 | 830 | 6.40 | 2,810 |
| 2.20 | 36 | 3.40 | 239 | 4.60 | 900 | | |
| 2.30 | 44 | 3.50 | 270 | 4.70 | 975 | | |
| 2.40 | 53 | 3.60 | 307 | 4.80 | 1,050 | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on 26 discharge measurements made during 1905. It is well defined between gage heights 3.5 feet and 6 feet. Below 3.5 feet the table is not so well defined.

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*Estimated monthly discharge of Pit River near Bieber, Cal., for 1905.*

[Drainage area, 2,948 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 2,960 | 213 | 1,036 | 63,700 | 0.351 | 0.405 |
| February | 2,270 | 349 | 1,083 | 60,150 | .367 | .382 |
| March | 2,270 | 349 | 1,101 | 67,700 | .373 | .430 |
| April | 2,665 | 147 | 950 | 56,530 | .322 | .359 |
| May | 270 | 109 | 166 | 10,210 | .056 | .065 |
| June | 190 | 44 | 103 | 6,129 | .035 | .039 |
| July | 92 | 29 | 51.8 | 3,185 | .018 | .021 |
| August | 29 | 2.2 | 9.73 | 598 | .0033 | .0038 |
| September | 2.2 | .8 | 1.23 | 73.2 | .00042 | .00047 |
| October | 44 | 2.2 | 15.4 | 947 | .0052 | .0060 |
| November | 92 | 44 | 76.1 | 4,528 | .026 | .029 |
| December 1-22 | 213 | 44 | 63.9 | 2,788 | .022 | .025 |
| The period | | | | 276,500 | | |

NOTE.—Discharge interpolated for missing gage heights in September, October, November, and December.

### SOUTH FORK OF PIT RIVER NEAR IVY, CAL.

This station was established January 11, 1904, by H. E. Green and J. S. Evans. It is located 3 miles west of Ivy post-office, at the outlet of Jess Valley.

The channel is straight for 200 feet above and 80 feet below the station. The current is sluggish at low-water stage. The right bank is low and subject to overflow in high water. The bed of the stream is composed of earth and is filled with vegetation at low-water stage.

Discharge measurements are made from a cable and car. The initial point for soundings is the foot of the post used for fastening the car on the left bank of the stream.

The gage is a vertical plank fastened to a tree on the left bank 50 feet above the station. It is read only at times discharge measurements are made, as it is impossible to get an observer on account of its isolated location. The bench mark is on a large bowlder 150 feet east of cabin on the right bank and below the station; elevation, 12.00 feet above the datum of the gage.

A description of this station, with gage height and discharge data, is contained in Water-Supply Paper No. 134, United States Geological Survey.

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*Discharge measurements of South Fork of Pit River near Ivy, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. feet.* | *Ft. per sec.* | *Feet.* | *Sec.-feet.* |
| January 1 | J. Y. Toler | 32 | 63 | 0.92 | 4.90 | 58 |
| January 13 | do | 28 | 37 | .62 | 3.80 | 23 |
| February 1 | do | 30 | 47 | 1.04 | 4.18 | 49 |
| February 17 | do | 28 | 42 | 1.00 | 4.00 | 42 |
| March 4 | do | 28 | 42 | 1.05 | 4.05 | 44 |
| March 17 | do | 31 | 63 | 1.46 | 4.72 | 93 |
| March 30 | do | 30 | 51 | 1.18 | 4.30 | 60 |
| April 13 | do | 33 | 61 | 1.41 | 4.60 | 86 |
| April 22 | do | 33 | 62 | 1.37 | 4.60 | 85 |
| May 12 | do | 66 | 104 | 1.52 | 5.33 | 158 |
| May 13 | do | 66 | 101 | 1.53 | 5.33 | 155 |
| May 25 | do | 85 | 112 | 1.41 | 5.40 | 158 |
| May 26 | do | 98 | 118 | 1.40 | 5.44 | 165 |
| June 5 | do | 107 | 145 | 1.34 | 5.68 | 195 |
| June 6 | do | 97 | 126 | 1.31 | 5.50 | 165 |
| June 17 | do | 39 | 80 | 1.32 | 5.05 | 106 |
| June 19 | do | 38 | 78 | 1.28 | 5.00 | 100 |
| July 1 | do | 24 | 22 | 1.86 | 4.15 | 41 |
| July 13 | do | 23 | 19.5 | 1.79 | 4.05 | 35 |
| July 14 | do | 23 | 18.3 | 1.75 | 4.00 | 32 |
| July 26 | do | 15 | 20 | 1.60 | 4.00 | 32 |
| July 27 | do | 15 | 20 | 1.60 | 4.00 | 32 |
| August 15 | do | 16 | 19.5 | 1.44 | 4.10 | 28 |
| August 16 | do | 16 | 19.8 | 1.41 | 4.10 | 28 |
| August 24 | do | 16 | 17.2 | 1.16 | 3.70 | 19 9 |
| September 5 | do | 6 | 8.6 | 1.42 | 3.20 | 12.2 |
| September 14 | do | 14 | 8.6 | 1.95 | 3.30 | 16.8 |
| October 3 | do | 15 | 7.2 | 1.97 | 3.20 | 14.2 |
| October 12 | do | 15 | 7.2 | 1.97 | 3.20 | 14.2 |
| October 13 | do | 15 | 7.2 | 2.00 | 3.20 | 14.4 |
| October 21 | do | 16 | 6.8 | 2.03 | 3.20 | 13.8 |
| November 1 | do | 15 | 7.2 | 2.03 | 3.20 | 14.6 |
| November 2 | do | 16 | 8.0 | 2.09 | 3.20 | 16.7 |
| November 14 | do | 16 | 8.4 | 2.13 | 3.20 | 17.9 |
| November 15 | do | 16 | 7.6 | 2.12 | 3.20 | 16.1 |

### WEST VALLEY CREEK NEAR LIKELY, CAL.

This station was established January 7, 1904, by H. E. Green and J. S. Evans. It is located 7 miles east of Likely, Cal., at the outlet of West Valley.

The channel is straight for 200 feet above and 100 feet below the station. The banks are high and not subject to overflow. The bed of the stream is rocky and not subject to change. The current is swift.

Discharge measurements are made from a cable and car, or by wading at low-water stage. The initial point for soundings is a juniper stump on the left bank, which is used for a tieing post for the car. After July 1, 1905, gagings were made at the ranch house near the upper rod. These gagings give a much less discharge than at the regular station. The gage is a vertical plank nailed to a juniper tree on the right bank of the creek. As no one could be obtained to read the station gage, a gage was placed 2 miles above the station near the ranch house, where an observer could be obtained. The gage as read at this point is not considered satisfactory for use in constructing a discharge curve for the gaging station, but only gives a general idea of the fluctuations in the flow of the stream.

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Numerous springs and swamps appear in the valley between the gaging station and the ranch house, giving a greater discharge at the gaging station than at this point. During 1905 the gage was read by Jasper L. Fountain. The bench mark is a point marked with paint on a large bowlder 30 feet from the creek on the left bank; elevation, 10.00 feet above the datum of the gage.

A description of this station, with gage height and discharge data, is contained in Water-Supply Paper No. 134, United States Geological Survey.

*Discharge measurements of West Valley Creek near Likely, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 12 | J. Y. Toler | 15 | 22 | 1.28 | 3.30 | 28 |
| January 31 | do | 15 | 23 | .96 | 3.20 | 22 |
| February 2 | do | 15 | 22 | .93 | 3.20 | 20 |
| February 16 | do | 15 | 24 | 1.09 | 3.22 | 26 |
| March 4 | do | 15 | 24 | 1.00 | 3.20 | 24 |
| March 5 | do | 15 | 24 | 1.00 | 3.20 | 24 |
| March 16 | do | 15 | 24 | 1.02 | 3.22 | 25 |
| March 17 | do | 15 | 32 | 2.16 | 3.70 | 69 |
| March 29 | do | 15 | 21 | 1.43 | 3.30 | 30 |
| March 31 | do | 15 | 21 | 1.42 | 3.30 | 30 |
| April 13 | do | 15 | 22 | 1.18 | 3.25 | 26 |
| April 22 | do | 15 | 19 | 1.19 | 3.20 | 23 |
| May 12 | do | 15 | 25 | 1.40 | 3.32 | 35 |
| May 13 | do | 15 | 26 | 1.46 | 3.35 | 38 |
| May 25 | do | 15 | 21 | 1.05 | 3.22 | 22 |
| May 26 | do | 15 | 22 | .95 | 3.19 | 21 |
| June 4 | do | 15 | 28 | 1.68 | 3.50 | 47 |
| June 5 | do | 15 | 26 | 1.50 | 3.40 | 39 |
| June 6 | do | 15 | 25 | 1.28 | 3.30 | 32 |
| June 17 | do | 15 | 22 | 1.18 | 3.20 | 26 |
| June 19 | do | 15 | 22 | 1.09 | 3.15 | 24 |
| July 1 | do | 3 | 4.4 | 3.84 | 3.10 | 16.9 |
| July 13 | do | 8 | 10.0 | 1.74 | 3.20 | 17.4 |
| July 14 | do | 8 | 10.0 | 1.74 | 3.20 | 17.4 |
| July 26 | do | 8 | 9.6 | 1.72 | 3.15 | 16.5 |
| August 15 | do | 8 | 10.0 | 1.70 | 3.15 | 17 |
| August 24 | do | 16 | 7.2 | 1.43 | 3.00 | 10.3 |
| September 5 | do | 21 | 13 | 1.02 | 3.10 | 13.2 |
| September 6 | do | 21 | 13.7 | 1.04 | 3.10 | 14.2 |
| September 14 | do | 17 | 7.4 | 1.53 | 3.10 | 11.3 |
| September 15 | do | 17 | 7.8 | 1.49 | 3.10 | 11.6 |
| October 3 | do | 18 | 8.4 | 1.65 | 3.10 | 13.9 |
| October 12 | do | 19 | 10.1 | 1.59 | 3.20 | 17.1 |
| October 13 | do | 19 | 10.4 | 1.68 | 3.20 | 17.5 |
| October 21 | do | 18 | 7.6 | 1.72 | 3.10 | 13.1 |
| October 22 | do | 18 | 7.8 | 1.73 | 3.10 | 13.5 |
| November 1 | do | 13 | 11.4 | 1.24 | 3.20 | 14.0 |
| November 14 | do | 13 | 11.0 | 1.32 | 3.20 | 14.5 |
| November 15 | do | 13 | 11.0 | 1.30 | 3.20 | 14.3 |

NOTE.—After July 1 gagings were made near upper gage.

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*Daily gage height, in feet, of West Valley Creek near Likely, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.3 | 3.2 | 3.2 | 4.5 | 3.15 | 3.2 | 3.2 | a 3.2 | 3.0 | a 3.1 | 3.15 | 3.1 |
| 2 | 3.3 | 3.2 | 3.2 | 3.4 | 3.15 | 3.2 | 3.2 | 3.2 | 3.0 | a 3.1 | 3.15 | 3.1 |
| 3 | 3.25 | 3.2 | 3.2 | 3.3 | 3.15 | 3.2 | 3.2 | 3.2 | 3.0 | a 3.1 | 3.15 | 3.15 |
| 4 | 3.25 | 3.2 | 3.15 | 3.3 | 3.15 | 3.2 | 3.2 | 3.2 | 3.1 | a 3.1 | 3.2 | 3.15 |
| 5 | 3.25 | 3.2 | 3.15 | 3.3 | 3.15 | 3.6 | 3.2 | 3.2 | 3.1 | a 3.1 | 3.2 | 3.15 |
| 6 | 3.2 | 3.2 | a 3.15 | 3.3 | 3.15 | 3.5 | 3.2 | 3.2 | 3.1 | a 3.1 | 3.2 | 3.15 |
| 7 | 3.2 | 3.2 | a 3.15 | 3.25 | 3.15 | 3.45 | 3.2 | 3.2 | 3.1 | a 3.1 | 3.2 | 3.15 |
| 8 | 3.2 | 3.2 | a 3.15 | 3.25 | 3.3 | 3.55 | 3.2 | 3.2 | 3.1 | a 3.2 | 3.2 | 3.1 |
| 9 | 3.2 | 3.2 | a 3.1 | 3.25 | 3.2 | 3.55 | 3.15 | 3.2 | 3.1 | a 3.2 | 3.2 | 3.15 |
| 10 | 3.2 | 3.2 | a 3.1 | 3.25 | 3.4 | 3.3 | 3.15 | 3.2 | 3.1 | a 3.2 | 3.2 | 3.15 |
| 11 | 3.2 | 3.2 | 3.1 | 3.25 | 3.3 | 3.3 | 3.15 | 3.2 | 3.1 | a 3.2 | 3.2 | 3.1 |
| 12 | 3.2 | 3.2 | 3.1 | 3.25 | 3.25 | 3.25 | 3.15 | 3.2 | 3.2 | a 3.2 | 3.2 | 3.15 |
| 13 | 3.2 | 3.2 | 3.15 | 3.25 | 3.2 | 3.25 | 3.15 | 3.2 | 3.2 | a 3.2 | 3.2 | 3.1 |
| 14 | 3.2 | 3.2 | 3.2 | 3.25 | 3.2 | 3.2 | 3.15 | 3.0 | 3.2 | a 3.2 | 3.2 | 3.25 |
| 15 | 3.2 | 3.2 | 3.2 | 3.3 | 3.2 | 3.2 | 3.15 | 3.0 | 3.2 | a 3.2 | 3.2 | 3.15 |
| 16 | 3.2 | 3.2 | 3.2 | 3.3 | 3.2 | 3.2 | 3.15 | 3.0 | 3.2 | a 3.2 | 3.2 | 3.1 |
| 17 | 3.25 | 3.2 | 3.65 | 3.3 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | a 3.2 | 3.2 | 3.15 |
| 18 | 3.25 | 3.2 | 3.4 | 3.25 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | a 3.1 | 3.2 | 3.1 |
| 19 | 3.3 | 3.2 | 3.5 | 3.2 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | a 3.1 | 3.2 | 3.1 |
| 20 | 3.3 | 3.2 | 3.35 | 3.2 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | a 3.1 | 3.6 | 3.15 |
| 21 | 3.3 | 3.2 | 3.5 | 3.2 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | a 3.1 | 3.4 | 3.1 |
| 22 | 3.25 | 3.2 | 3.5 | 3.2 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | 3.1 | 3.8 | 3.1 |
| 23 | 3.2 | 3.2 | 3.35 | 3.2 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | 3.1 | 3.25 | 3.15 |
| 24 | 3.2 | 3.2 | 3.3 | 3.2 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | 3.1 | 3.1 | 3.1 |
| 25 | 3.2 | 3.2 | 3.3 | 3.2 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | 3.1 | 3.1 | 3.15 |
| 26 | 3.2 | 3.2 | 3.4 | 3.15 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | 3.1 | 3.1 | 3.1 |
| 27 | 3.2 | 3.2 | 3.7 | 3.15 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | 3.1 | 3.15 | 3.1 |
| 28 | 3.2 | 3.2 | 3.4 | 3.15 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | 3.1 | 3.2 | 3.1 |
| 29 | 3.2 | ..... | 3.35 | 3.15 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | 3.1 | 3.1 | 3.15 |
| 30 | 3.2 | ..... | 3.4 | 3.15 | 3.2 | 3.2 | 3.15 | 3.0 | a 3.2 | 3.1 | 3.1 | 3.1 |
| 31 | 3.2 | ..... | 3.5 | ..... | 3.2 | ..... | 3.2 | 3.0 | ..... | 3.1 | ..... | 3.6 |

a Estimated.

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*Daily discharge, in second-feet, of West Valley Creek near Likely, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 28 | 21 | 24 | 188 | 22 | 23 | 20 | 20 | 10 | 16 | 12 |
| 2 | 28 | 20 | 24 | 38 | 22 | 23 | 20 | 20 | 9 | 15 | 12 |
| 3 | 25 | 20 | 24 | 30 | 22 | 24 | 20 | 20 | 9 | 14 | 12 |
| 4 | 25 | 20 | 24 | 30 | 22 | 24 | 19 | 20 | 13 | 14 | 14 |
| 5 | 25 | 21 | 24 | 30 | 23 | 57 | 19 | 20 | 13 | 14 | 14 |
| 6 | 22 | 21 | 21 | 30 | 23 | 47 | 19 | 20 | 14 | 15 | 14 |
| 7 | 22 | 21 | 21 | 26 | 23 | 43 | 18 | 20 | 14 | 15 | 14 |
| 8 | 22 | 22 | 21 | 26 | 32 | 52 | 18 | 20 | 13 | 16 | 14 |
| 9 | 22 | 22 | 19 | 26 | 26 | 52 | 16 | 20 | 13 | 16 | 15 |
| 10 | 22 | 22 | 19 | 26 | 42 | 32 | 16 | 20 | 12 | 16 | 15 |
| 11 | 22 | 23 | 19 | 26 | 33 | 32 | 15 | 20 | 12 | 17 | 15 |
| 12 | 22 | 23 | 19 | 26 | 30 | 29 | 15 | 20 | 26 | 17 | 15 |
| 13 | 22 | 24 | 21 | 26 | 27 | 29 | 15 | 20 | 26 | 18 | 14 |
| 14 | 22 | 24 | 24 | 26 | 27 | 26 | 15 | 11 | 26 | 18 | 14 |
| 15 | 22 | 25 | 25 | 30 | 27 | 26 | 15 | 11 | 26 | 17 | 14 |
| 16 | 22 | 26 | 25 | 30 | 26 | 26 | 15 | 11 | 26 | 16 | 14 |
| 17 | 25 | 26 | 63 | 30 | 26 | 26 | 15 | 10 | 26 | 16 | 14 |
| 18 | 25 | 26 | 38 | 26 | 26 | 26 | 15 | 10 | 25 | 15 | 14 |
| 19 | 28 | 26 | 48 | 23 | 24 | 26 | 16 | 10 | 24 | 14 | 14 |
| 20 | 28 | 26 | 34 | 23 | 24 | 26 | 16 | 10 | 24 | 14 | ..... |
| 21 | 28 | 26 | 48 | 23 | 24 | 25 | 16 | 10 | 23 | 13 | ..... |
| 22 | 25 | 26 | 48 | 23 | 23 | 25 | 16 | 10 | 22 | 14 | ..... |
| 23 | 22 | 25 | 34 | 23 | 23 | 24 | 16 | 10 | 21 | 14 | ..... |
| 24 | 22 | 25 | 30 | 23 | 21 | 24 | 16 | 10 | 21 | 13 | ..... |
| 25 | 22 | 25 | 30 | 23 | 21 | 23 | 16 | 10 | 20 | 13 | ..... |
| 26 | 22 | 25 | 38 | 21 | 21 | 23 | 17 | 10 | 20 | 12 | ..... |
| 27 | 22 | 25 | 69 | 21 | 21 | 22 | 17 | 10 | 19 | 12 | ..... |
| 28 | 22 | 25 | 38 | 21 | 21 | 22 | 17 | 10 | 18 | 11 | ..... |
| 29 | 22 | ..... | 34 | 21 | 22 | 21 | 17 | 10 | 18 | 11 | ..... |
| 30 | 22 | ..... | 38 | 21 | 22 | 21 | 17 | 10 | 17 | 10 | ..... |
| 31 | 22 | ..... | 48 | ..... | 23 | ..... | 20 | 10 | ..... | 10 | ..... |

NOTE.—Daily discharge obtained by indirect method for shifting channel, as no measurements were made later than November 19. No estimate has been made for the remainder of the year.

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*Estimated monthly discharge of West Valley Creek near Likely, Cal., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 28 | 22 | 23.5 | 1,445 |
| February | 26 | 20 | 23.6 | 1,311 |
| March | 69 | 19 | 32.0 | 1,968 |
| April | 188 | 21 | 31.2 | 1,856 |
| May | 42 | 21 | 24.8 | 1,525 |
| June | 57 | 21 | 29.3 | 1,744 |
| July | 20 | 15 | 16.8 | 1,033 |
| August | 20 | 10 | 14.3 | 879 |
| September | 26 | 9 | 18.7 | 1,113 |
| October | 18 | 10 | 14.4 | 885 |
| November 1–19 | 15 | 12 | 13.9 | 327 |
| The period | | | | 14,290 |

### ASH CREEK AT ADIN, CAL.

This station was established March 13, 1904, by J. S. Evans and William Busch. It was originally located one-fourth of a mile above the town of Adin. During the summer the closing of the waste gates in the dam at Adin interfered with the discharge at this point to such an extent that on August 15, 1904, the station was reestablished at a point 100 feet below the wagon bridge in the town of Adin, Cal., which is about 500 feet below the dam.

The channel is straight for 200 feet above and 200 feet below the station. The left bank is high, but the right bank is subject to overflow from the side channel which, in flood diverts water from above the station. The bed of the stream is gravelly and not subject to change.

Discharge measurements are made from a suspension footbridge constructed with one-half inch cables.

The gage is a vertical plank fastened to a tree on the left bank of the stream. During 1905 the gage was read once each day by H. Williams.

A description of this station, with gage heights and discharged data, is contained in Water Supply Paper No. 134, United States Geological Survey.

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*Discharge measurements of Ash Creek River at Adin, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 7 | J. Y. Toler | 32 | 50 | 0.90 | 1.96 | 45 |
| January 21 | do | 34 | 69 | 1.23 | 2.40 | 85 |
| January 25 | do | 35 | 92 | 1.35 | 2.89 | 124 |
| Do | do | 35 | 95 | 1.33 | 3.00 | 126 |
| February 8 | do | 34 | 70 | .99 | 2.30 | 69 |
| February 11 | do | 36 | 78 | 1.47 | 2.80 | 115 |
| February 12 | do | 36 | 76 | 1.30 | 2.50 | 99 |
| February 23 | do | 36 | 108 | 1.57 | 3.30 | 170 |
| February 26 | do | 36 | 93 | 1.44 | 2.90 | 134 |
| March 10 | do | 35 | 67 | 1.07 | 2.30 | 72 |
| March 12 | do | 35 | 67 | 1.10 | 2.30 | 74 |
| March 13 | do | 35 | 68 | 1.16 | 2.35 | 79 |
| March 25 | do | 36 | 114 | 1.27 | 3.60 | 145 |
| April 5 | do | 36 | 125 | 1.85 | 3.95 | 231 |
| April 8 | do | 36 | 107 | 1.72 | 3.55 | 183 |
| Do | do | 36 | 103 | 1.65 | 3.40 | 171 |
| April 16 | do | 35 | 82 | 1.45 | 2.80 | 119 |
| April 18 | do | 35 | 79 | 1.34 | 2.70 | 106 |
| May 2 | do | 35 | 80 | 1.33 | 2.70 | 106 |
| May 3 | do | 34 | 60 | .98 | 2.20 | 59 |
| May 4 | do | 34 | 63 | 1.08 | 2.10 | 68 |
| May 17 | do | 33 | 56 | .86 | 1.90 | 48 |
| May 18 | do | 33 | 54 | .85 | 1.90 | 46 |
| May 19 | do | 33 | 53 | .79 | 1.85 | 42 |
| May 20 | do | 33 | 53 | .76 | 1.80 | 40 |
| June 10 | do | 45 | 28 | 1.08 | 1.80 | 30 |
| June 11 | do | 45 | 27 | 1.05 | 1.75 | 28 |
| June 13 | do | 44 | 26 | .96 | 1.70 | 25 |
| July 6 | do | 28 | 22 | .93 | 1.65 | 20 |
| July 18 | do | 28 | 23 | .91 | 1.65 | 21 |
| July 21 | do | 26 | 18.9 | 1.22 | 1.70 | 23 |
| August 8 | do | 25 | 15.4 | 1.28 | 1.60 | 19.7 |
| August 10 | do | 25 | 15.4 | 1.29 | 1.60 | 19.9 |
| August 17 | do | 28 | 19.2 | 1.10 | 1.65 | 20 |
| August 20 | do | 28 | 18.4 | .98 | 1.60 | 18.1 |
| August 29 | do | 27 | 16.7 | .89 | 1.50 | 14.9 |
| August 30 | do | 27 | 16.7 | .83 | 1.50 | 13.8 |
| September 10 | do | 28 | 19.2 | .98 | 1.60 | 18.9 |
| September 11 | do | 29 | 21 | 1.05 | 1.70 | 22 |
| September 20[a] | do | 7 | 2.5 | .92 | 1.00 | 2.3 |
| September 21 | do | 32 | 49 | .49 | 1.70 | 24 |
| October 8 | do | 30 | 19.2 | 1.67 | 1.70 | 32 |
| October 9 | do | 32 | 50 | .59 | 1.70 | 29 |
| October 17 | do | 30 | 19.2 | 1.41 | 1.70 | 27 |
| October 18 | do | 34 | 51 | .63 | 1.80 | 32 |
| October 26 | do | 26 | 50 | .63 | 1.80 | 31 |
| October 28 | do | 36 | 57 | .87 | 2.00 | 50 |
| November 8 | do | 34 | 50 | .64 | 1.80 | 32 |
| November 9 | do | 35 | 53 | .84 | 1.90 | 44 |

[a] Water held back by dam above station.

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*Daily gage height, in feet, of Ash Creek at Adin, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.5 | 3.4 | 2.5 | 4.1 | 2.3 | 1.9 | 1.7 | 1.5 | 1.6 | 1.7 | 1.9 | 1.8 |
| 2 | 2.4 | 5.9 | 2.5 | 6.0 | 2.2 | 1.9 | 1.7 | 1.6 | 1.7 | 1.7 | 1.9 | 1.8 |
| 3 | 2.2 | 3.5 | 2.5 | 6.0 | 2.1 | 1.9 | 1.7 | 1.6 | 1.7 | 1.7 | 1.9 | 1.8 |
| 4 | 1.9 | 3.4 | 2.5 | 4.6 | 2.1 | 1.9 | 1.6 | 1.6 | 1.7 | 1.7 | 1.9 | 1.8 |
| 5 | 1.9 | 3.4 | 2.5 | 4.6 | 2.1 | 1.9 | 1.5 | 1.6 | 1.7 | 1.7 | 1.9 | 1.8 |
| 6 | 1.9 | 3.4 | 2.5 | 4.0 | 2.1 | 1.8 | 1.5 | 1.6 | 1.8 | 1.7 | 1.9 | 1.8 |
| 7 | 1.9 | 3.4 | 2.5 | 3.7 | 2.1 | 1.8 | 1.5 | 1.6 | 1.8 | 1.7 | 1.9 | 1.8 |
| 8 | 1.9 | 3.2 | 2.5 | 3.7 | 2.1 | 1.8 | 1.5 | 1.6 | 1.8 | 1.7 | 1.9 | 1.8 |
| 9 | 1.9 | 2.5 | 2.4 | 3.2 | 2.1 | 1.8 | 1.5 | 1.6 | 1.8 | 1.7 | 1.9 | 1.8 |
| 10 | 1.9 | 2.4 | 2.4 | 3.2 | 2.2 | 1.8 | 1.5 | 1.6 | 1.9 | 1.8 | 1.9 | 1.8 |
| 11 | 1.9 | 2.3 | 2.4 | 3.1 | 2.2 | 1.8 | 1.5 | 1.6 | 1.9 | 1.8 | 1.9 | 1.8 |
| 12 | 1.9 | 2.3 | 2.4 | 3.1 | 2.2 | 1.8 | 1.5 | 1.6 | 1.8 | 1.9 | 1.9 | 1.8 |
| 13 | 2.0 | 2.2 | 2.4 | 3.0 | 2.2 | 1.8 | 1.5 | 1.6 | 1.8 | 1.9 | 1.9 | 1.8 |
| 14 | 2.0 | 2.1 | 2.4 | 3.0 | 2.2 | 1.8 | 1.5 | 1.6 | 1.8 | 1.9 | 1.9 | 1.8 |
| 15 | 2.0 | 2.1 | 2.4 | 3.0 | 2.1 | 1.8 | 1.5 | 1.6 | 1.8 | 1.9 | 1.9 | 1.8 |
| 16 | 4.0 | 2.1 | 2.4 | 3.0 | 2.1 | 1.8 | 1.5 | 1.6 | 1.8 | 1.9 | 1.8 | 1.8 |
| 17 | 2.5 | 2.2 | 3.1 | 2.8 | 2.1 | 1.8 | 1.5 | 1.6 | 1.7 | 1.7 | 1.8 | 1.8 |
| 18 | 2.0 | 3.1 | 5.1 | 2.8 | 2.2 | 1.8 | 1.5 | 1.6 | 1.7 | 1.7 | 1.8 | 1.8 |
| 19 | 2.8 | 5.9 | 6.2 | 2.8 | 2.2 | 1.8 | 1.5 | 1.6 | 1.7 | 1.7 | 1.8 | 1.8 |
| 20 | 2.4 | 6.0 | 4.3 | 2.8 | 2.3 | 1.8 | 1.5 | 1.6 | 1.6 | 1.7 | 1.8 | 1.8 |
| 21 | 2.4 | 3.4 | 4.6 | 2.8 | 2.3 | 1.7 | 1.5 | 1.6 | 1.6 | 1.7 | 1.8 | 1.8 |
| 22 | 4.1 | 3.3 | 4.6 | 2.8 | 2.3 | 1.7 | 1.5 | 1.6 | 1.6 | 1.7 | 1.8 | 1.8 |
| 23 | 4.6 | 3.3 | 3.8 | 2.7 | 2.1 | 1.7 | 1.5 | 1.6 | 1.6 | 1.7 | 1.8 | 1.8 |
| 24 | 4.6 | 2.6 | 5.4 | 2.7 | 2.1 | 1.7 | 1.5 | 1.6 | 1.6 | 1.7 | 1.8 | 1.8 |
| 25 | 3.0 | 2.6 | 3.6 | 2.7 | 1.9 | 1.7 | 1.5 | 1.7 | 1.6 | 1.7 | 1.8 | 1.8 |
| 26 | 2.4 | 2.3 | 9.0 | 2.7 | 1.9 | 1.7 | 1.5 | 1.7 | 1.6 | 1.7 | 1.8 | 1.8 |
| 27 | 2.3 | 2.3 | 4.6 | 2.7 | 1.9 | 1.7 | 1.5 | 1.7 | 1.6 | 1.8 | 1.8 | 1.8 |
| 28 | 2.3 | 2.5 | 4.1 | 2.8 | 1.9 | 1.7 | 1.5 | 1.6 | 1.6 | 1.8 | 1.8 | 1.8 |
| 29 | 2.3 | ..... | 4.2 | 2.8 | 1.9 | 1.7 | 1.5 | 1.6 | 1.6 | 1.8 | 1.8 | 1.8 |
| 30 | 4.5 | ..... | 4.2 | 2.8 | 1.9 | 1.7 | 1.5 | 1.6 | 1.6 | 1.8 | 1.8 | 1.8 |
| 31 | 4.5 | ..... | 4.1 | ..... | 1.9 | ..... | 1.5 | 1.6 | ..... | 1.9 | ..... | 1.8 |

*Station rating table for Ash Creek at Adin, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.50 | 14 | 2.60 | 97 | 3.70 | 205 | 4.80 | 342 |
| 1.60 | 20 | 2.70 | 106 | 3.80 | 216 | 4.90 | 356 |
| 1.70 | 27 | 2.80 | 115 | 3.90 | 227 | 5.00 | 370 |
| 1.80 | 34 | 2.90 | 124 | 4.00 | 238 | 5.20 | 400 |
| 1.90 | 41 | 3.00 | 134 | 4.10 | 250 | 5.40 | 430 |
| 2.00 | 48 | 3.10 | 144 | 4.20 | 262 | 5.60 | 462 |
| 2.10 | 56 | 3.20 | 154 | 4.30 | 274 | 5.80 | 494 |
| 2.20 | 64 | 3.30 | 164 | 4.40 | 287 | 6.00 | 526 |
| 2.30 | 72 | 3.40 | 174 | 4.50 | 300 | 6.20 | 560 |
| 2.40 | 80 | 3.50 | 184 | 4.60 | 314 | | |
| 2.50 | 88 | 3.60 | 194 | 4.70 | 328 | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on 49 discharge measurements made during 1905. It is well defined between gage heights 1.5 feet and 4 feet. Above 4 feet the table is a rough approximation.

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*Estimated monthly discharge of Ash Creek at Adin, Cal., for 1905.*

[Drainage area, 260 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 314 | 41 | 107 | 6,579 | 0.412 | 0.475 |
| February | 526 | 56 | 158 | 8,775 | .608 | .633 |
| March | 1,120 | 80 | 214 | 13,160 | .823 | .949 |
| April | 526 | 106 | 176 | 10,470 | .677 | .755 |
| May | 72 | 41 | 56.7 | 3,486 | .218 | .251 |
| June | 41 | 27 | 32.8 | 1,952 | .126 | .141 |
| July | 27 | 14 | 15.5 | 953 | .060 | .069 |
| August | 27 | 14 | 20.5 | 1,260 | .079 | .091 |
| September | 41 | 20 | 27.2 | 1,618 | .105 | .117 |
| October | 41 | 27 | 31.1 | 1,912 | .120 | .138 |
| November | 41 | 34 | 37.5 | 2,231 | .144 | .161 |
| December | 34 | 34 | 34 | 2,091 | .131 | .151 |
| The year | 1,120 | 14 | 75.9 | 54,490 | .292 | 3.93 |

### McCLOUD RIVER NEAR GREGORY, CAL.

This station was established March 23, 1902, in cooperation with the McCloud River Electric Company. It is located at John's Camp, near Hirze Mountain, 14 miles east of Gregory Post-office, Cal. Baird Station, on the Southern Pacific Railroad, is just across Sacramento River from Gregory.

The channel is straight for 300 feet above and 600 feet below the gaging station. The current is swift at all stages. The banks are high and wooded and not liable to overflow. The bed is composed of limestone on the sides, with some large river gravel and bowlders in the center of the channel.

Measurements are made from a car suspended from a cable. The initial point for soundings is at the gage rod on the right bank of the stream. A line is placed 150 feet below the cable, marking a course for float measurements during floods.

The gage rod is a timber nailed and wired to a tree on the right bank. The bench mark is a point marked with a ring of white paint on the top of a bowlder 10 feet upstream from the 10-foot mark on the cable; elevation, 21.19 feet above the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 100 and 134 of the United States Geological Survey.

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*Discharge measurements of McCloud River near Gregory, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| February 21 | O. W. Peterson | 114 | 830 | 6.43 | 4.58 | 5,337 |
| February 22 | do | 114 | 759 | 5.47 | 3.95 | 4,155 |
| February 22 | do | 114 | 766 | 5.38 | 3.98 | 4,120 |
| August 6 | Peterson & Lee | 103 | 543 | 2.55 | 1.63 | 1,386 |

*Daily gage height, in feet, of McCloud River near Gregory, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.9 | 3.85 | 2.9 | 3.4 | 2.8 | 2.1 | 1.8 | 1.65 | 1.55 | 1.55 | 1.5 | 1.55 |
| 2 | 2.6 | 4.5 | 2.8 | 3.3 | 2.7 | 2.2 | 1.8 | 1.65 | 1.55 | 1.55 | 1.5 | 1.55 |
| 3 | 2.45 | 3.85 | 2.8 | 3.25 | 2.65 | 2.1 | 1.8 | 1.65 | 1.55 | 1.55 | 1.5 | 1.55 |
| 4 | 2.3 | 3.7 | 2.75 | 3.2 | 2.6 | 2.1 | 1.8 | 1.65 | 1.55 | 1.55 | 1.5 | 1.55 |
| 5 | 2.2 | 3.6 | 2.7 | 3.1 | 2.5 | 2.1 | 1.8 | 1.6 | 1.55 | 1.55 | 1.5 | 1.55 |
| 6 | 2.2 | 3.6 | 2.7 | 3.0 | 2.6 | 2.05 | 1.8 | 1.65 | 1.55 | 1.55 | 1.5 | 1.55 |
| 7 | 2.15 | 3.5 | 2.65 | 2.9 | 2.7 | 2.05 | 1.8 | 1.6 | 1.55 | 1.6 | 1.5 | 1.55 |
| 8 | 2.1 | 3.3 | 2.65 | 2.85 | 2.8 | 2.0 | 1.8 | 1.6 | 1.55 | 1.55 | 1.5 | 1.55 |
| 9 | 2.0 | 3.2 | 2.6 | 2.8 | 2.7 | 2.0 | 1.8 | 1.6 | 1.56 | 1.55 | 1.5 | 1.55 |
| 10 | 2.0 | 3.1 | 2.6 | 2.7 | 2.7 | 2.0 | 1.8 | 1.6 | 1.55 | 1.55 | 1.5 | 1.55 |
| 11 | 2.0 | 3.0 | 2.7 | 2.7 | 2.7 | 2.0 | 1.8 | 1.6 | 1.55 | 1.55 | 1.5 | 1.55 |
| 12 | 1.95 | 2.95 | 3.05 | 2.6 | 2.6 | 2.0 | 1.75 | 1.6 | 1.55 | 1.55 | 1.5 | 1.55 |
| 13 | 2.05 | 2.7 | 4.6 | 2.6 | 2.6 | 1.95 | 1.75 | 1.6 | 1.55 | 1.55 | 1.5 | 1.55 |
| 14 | 3.1 | 2.6 | 6.8 | 2.55 | 2.55 | 1.95 | 1.75 | 1.6 | 1.55 | 1.55 | 1.5 | 1.55 |
| 15 | 3.25 | 2.5 | 5.25 | 2.6 | 2.5 | 1.9 | 1.75 | 1.6 | 1.55 | 1.55 | 1.5 | 1.55 |
| 16 | 3.3 | 2.5 | 4.6 | 2.8 | 2.5 | 1.9 | 1.7 | 1.6 | 1.55 | 1.55 | 1.5 | 1.55 |
| 17 | 3.1 | 2.4 | 4.15 | 2.6 | 2.5 | 1.9 | 1.7 | 1.6 | 1.55 | 1.55 | 1.5 | 1.55 |
| 18 | 3.0 | 2.5 | 4.0 | 2.75 | 2.5 | 1.9 | 1.7 | 1.6 | 1.55 | 1.55 | 1.55 | 1.55 |
| 19 | 3.0 | 3.4 | 4.4 | 2.9 | 2.4 | 1.9 | 1.7 | 1.6 | 1.56 | 1.55 | 1.55 | 1.6 |
| 20 | 2.95 | 5.3 | 4.7 | 2.85 | 2.4 | 1.9 | 1.7 | 1.6 | 1.55 | 1.55 | 1.55 | 1.55 |
| 21 | 4.1 | 4.7 | 5.2 | 2.8 | 2.3 | 1.85 | 1.7 | 1.6 | 1.55 | 1.55 | 1.55 | 1.55 |
| 22 | 8.05 | 3.9 | 4.7 | 2.8 | 2.25 | 1.85 | 1.7 | 1.6 | 1.55 | 1.55 | 1.55 | 1.55 |
| 23 | 7.4 | 3.6 | 4.35 | 2.7 | 2.3 | 1.85 | 1.7 | 1.6 | 1.55 | 1.55 | 1.55 | 1.55 |
| 24 | 6.2 | 3.35 | 4.0 | 2.7 | 2.2 | 1.85 | 1.7 | 1.6 | 1.55 | 1.55 | 1.5 | 1.55 |
| 25 | 6.6 | 3.1 | 3.8 | 2.7 | 2.2 | 1.85 | 1.7 | 1.6 | 1.55 | 1.55 | 1.55 | 1.55 |
| 26 | 5.15 | 3.1 | 4.3 | 2.7 | 2.3 | 1.85 | 1.65 | 1.6 | 1.55 | 1.55 | 1.55 | 1.55 |
| 27 | 4.25 | 3.0 | 4.0 | 2.7 | 2.2 | 1.8 | 1.65 | 1.55 | 1.55 | 1.55 | 1.55 | 1.55 |
| 28 | 3.8 | 2.9 | 3.9 | 2.6 | 2.2 | 1.8 | 1.65 | 1.55 | 1.55 | 1.55 | 1.55 | 1.55 |
| 29 | 3.45 | ..... | 3.9 | 2.6 | 2.2 | 1.8 | 1.65 | 1.55 | 1.55 | 1.55 | 1.55 | 1.55 |
| 30 | 3.25 | ..... | 3.6 | 2.7 | 2.2 | 1.8 | 1.65 | 1.55 | 1.55 | 1.55 | 1.55 | 1.55 |
| 31 | 3.25 | ..... | 3.6 | ..... | 2.1 | ..... | 1.65 | 1.55 | ..... | 1.5 | ..... | 1.55 |

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*Station rating table for McCloud River near Gregory, Cal., from September 23, 1902, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.00 | 1,090 | 2.40 | 2,042 | 3.80 | 3,860 | 5.40 | 7,170 |
| 1.10 | 1,132 | 2.50 | 2,140 | 3.90 | 4,030 | 5.60 | 7,630 |
| 1.20 | 1,178 | 2.60 | 2,242 | 4.00 | 4,210 | 5.80 | 8,110 |
| 1.30 | 1,228 | 2.70 | 2,349 | 4.10 | 4,395 | 6.00 | 8,600 |
| 1.40 | 1,282 | 2.80 | 2,461 | 4.20 | 4,585 | 6.20 | 9,120 |
| 1.50 | 1,340 | 2.90 | 2,578 | 4.30 | 4,785 | 6.40 | 9,650 |
| 1.60 | 1,402 | 3.00 | 2,700 | 4.40 | 4,990 | 6.60 | 10,190 |
| 1.70 | 1,468 | 3.10 | 2,825 | 4.50 | 5,200 | 6.80 | 10,740 |
| 1.80 | 1,538 | 3.20 | 2,955 | 4.60 | 5,410 | 7.00 | 11,300 |
| 1.90 | 1,612 | 3.30 | 3,090 | 4.70 | 5,625 | 7.20 | 11,870 |
| 2.00 | 1,690 | 3.40 | 3,230 | 4.80 | 5,840 | 7.40 | 12,450 |
| 2.10 | 1,772 | 3.50 | 3,380 | 4.90 | 6,060 | 7.60 | 13,040 |
| 2.20 | 1,858 | 3.60 | 3,535 | 5.00 | 6,280 | 7.80 | 13,640 |
| 2.30 | 1,948 | 3.70 | 3,695 | 5.20 | 6,720 | 8.00 | 14,250 |

NOTE.—The above table is applicable only for open-channel conditions. It is based on 10 discharge measurements made during 1902–1905. It is fairly well defined between gage heights 1.5 feet and 4.6 feet. The table has been extended beyond these limits. Above 8 feet the discharge is a rough approximation.

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*Estimated monthly discharge of McCloud River near Gregory, Cal., for 1902–1905.*

[Drainage, 608 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| 1902 | | | | | | |
| September 23 to 30 | 1,340 | 1,282 | 1,333 | 21,150 | 2.19 | 0.651 |
| October | 2,140 | 1,228 | 1,372 | 84,360 | 2.26 | 2.61 |
| November | 12,740 | 1,282 | 2,799 | 166,600 | 4.60 | 5.13 |
| December | 6,060 | 1,538 | 2,576 | 158,400 | 4.24 | 4.89 |
| 1903 | | | | | | |
| January | 13,340 | 1,538 | 2,847 | 175,100 | 4.68 | 5.40 |
| February | 2,578 | 1,772 | 2,046 | 113,600 | 3.37 | 3.51 |
| March | 11,870 | 2,042 | 3,723 | 228,900 | 6.12 | 7.06 |
| April | 6,060 | 2,242 | 2,819 | 167,700 | 4.64 | 5.18 |
| May | 2,242 | 1,612 | 1,913 | 117,600 | 3.15 | 3.63 |
| June | 1,690 | 1,468 | 1,545 | 91,930 | 2.54 | 2.83 |
| July | 1,468 | 1,340 | 1,373 | 84,420 | 2.26 | 2.61 |
| August | 1,352 | 1,311 | 1,323 | 81,350 | 2.18 | 2.51 |
| September | 1,311 | 1,282 | 1,305 | 77,650 | 2.15 | 2.40 |
| October | 1,435 | 1,282 | 1,317 | 80,980 | 2.17 | 2.50 |
| November | 14,560 | 1,282 | 3,475 | 206,800 | 5.72 | 6.38 |
| December | 2,263 | 1,455 | 1,829 | 112,500 | 3.01 | 3.47 |
| The year | 14,560 | 1,282 | 2,126 | 1,539,000 | 3.50 | 47.48 |
| 1904 | | | | | | |
| January | 2,042 | 1,503 | 1,652 | 101,600 | 2.72 | 3.14 |
| February | 39,500 | 1,468 | 6,153 | 353,900 | 10.12 | 10.92 |
| March | 41,000 | 3,380 | 9,310 | 572,400 | 15.31 | 17.65 |
| April | 7,285 | 4,120 | 5,468 | 325,400 | 8.99 | 10.03 |
| May | 4,490 | 3,090 | 3,756 | 230,900 | 6.18 | 7.12 |
| June | 2,890 | 1,858 | 2,218 | 132,000 | 3.65 | 4.07 |
| July | 1,858 | 1,612 | 1,746 | 107,400 | 2.87 | 3.31 |
| August | 1,612 | 1,503 | 1,572 | 96,660 | 2.59 | 2.99 |
| September | 1,815 | 1,468 | 1,512 | 89,970 | 2.49 | 2.78 |
| October | 9,785 | 1,503 | 2,697 | 165,800 | 4.44 | 5.12 |
| November | 2,140 | 1,503 | 1,640 | 97,590 | 2.70 | 3.01 |
| December | 4,585 | 1,575 | 1,844 | 113,400 | 3.03 | 3.49 |
| The year | 41,000 | 1,468 | 3,297 | 2,387,000 | 5.42 | 73.63 |
| 1905 | | | | | | |
| January | 14,400 | 1,651 | 3,854 | 237,000 | 6.34 | 7.31 |
| February | 6,945 | 2,042 | 3,284 | 182,400 | 5.40 | 5.62 |
| March | 10,740 | 2,242 | 4,062 | 249,800 | 6.68 | 7.70 |
| April | 3,230 | 2,191 | 2,490 | 148,200 | 4.10 | 4.57 |
| May | 2,461 | 1,772 | 2,112 | 129,900 | 3.47 | 4.00 |
| June | 1,858 | 1,538 | 1,648 | 98,060 | 2.71 | 3.02 |
| July | 1,538 | 1,435 | 1,491 | 91,680 | 2.45 | 2.82 |
| August | 1,435 | 1,371 | 1,402 | 86,210 | 2.31 | 2.66 |
| September | 1,371 | 1,371 | 1,371 | 81,580 | 2.25 | 2.51 |
| October | 1,402 | 1,340 | 1,371 | 84,300 | 2.25 | 2.59 |
| November | 1,371 | 1,340 | 1,352 | 80,450 | 2.22 | 2.48 |
| December | 1,402 | 1,371 | 1,372 | 84,360 | 2.26 | 2.61 |
| The year | 14,400 | 1,340 | 2,151 | 1,554,000 | 3.54 | 47.89 |

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## MISCELLANEOUS MEASUREMENTS IN PIT RIVER DRAINAGE BASIN.

The following miscellaneous measurements were made in the Pit River drainage basin during 1905:

*Cottonwood Creek, near Lakeview, Oreg.*—This stream is tributary to Goose Lake. A measurement was made June 28, 1905, by S. G. Bennett and J. Y. Toler, one-half mile below Wilshire's sawmill and 10 miles above Lakeview, Oreg.

Width, 12.7 feet; area, 4.7 square feet; mean velocity, 1.55 feet per second; discharge, 7.3 second-feet.

*Corporation ditch, near Likely, Cal.*—This ditch diverts water from the South Fork of Pit River above Likely, Cal. The following measurements were made below head-gate, 2 miles east of Likely, Cal.:

June 7: Width, 5.7 feet; area, 16.3 square feet; mean velocity, 1.42 feet per second; discharge, 23 second-feet.

June 20: Width, 5.6 feet; area, 16.6 square feet; mean velocity, 1.41 feet per second; discharge, 24 second-feet.

September 6: Width, 7.0 feet; area, 19.9 square feet; mean velocity, 1.46 feet per second; discharge, 29 second-feet.

*Duke's ditch, near Likely, Cal.*—This ditch diverts water from the South Fork of Pit River. The following measurements were made in flume, 400 yards below head-gate, by John Y. Toler:

June 7: Width, 3 feet; area, 2.88 square feet; mean velocity, 4.83 feet per second; discharge, 13.9 second-feet.

June 20: Width, 3 feet; area, 2.3 square feet; mean velocity, 4.25 feet per second; discharge, 9.8 second-feet.

*Fitz Hugh Creek, near Alturas, Cal.*—This creek is tributary to Pit River. The following measurements were made at Doten's ranch, 10 miles south of Alturas, by John Y. Toler:

July 2: Width, 8.5 feet; area, 2.8 square feet; mean velocity, 0.64 foot per second; discharge, 1.8 second-feet.

July 25: Width, 8.4 feet; area, 2.7 square feet; mean velocity, 0.52 foot per second; discharge, 1.4 second-feet.

September 7: Width, 7.0 feet; area, 2.8 square feet; mean velocity, 0.64 foot per second; discharge, 1.8 second-feet.

September 16: Width, 8 feet; area, 3.6 square feet; mean velocity, 0.78 foot per second; discharge, 2.8 second-feet.

*Ganstad's ditch, near Likely, Cal.*—This ditch diverts water from the South Fork of the Pit River. The following measurements were made at head-gate, 2 miles east of Likely, Cal., by John Y. Toler:

June 8: Width, 6.6 feet; area, 10.5 square feet; mean velocity, 0.66 foot per second; discharge, 6.9 second-feet.

July 2: Width, 6.6 feet; area, 10.5 square feet; mean velocity, 0.83 foot per second; discharge, 8.7 second-feet.

*Gooch's ditch, near Lookout, Cal.*—This ditch diverts water from Pit River. A measurement was made 250 yards above bridge at Lookout on June 13 by John Y. Toler.

Width, 14.5 feet; area, 25 square feet; mean velocity, 0.48 foot per second; discharge, 12 second-feet.

*E. Lauer and Son's ditch near Alturas, Cal.*—This ditch diverts water from Pit River above the town of Alturas, Cal. A measurement was made in flume at XL ranch, 9 miles north of the town of Alturas, Cal., on May 23, by Jno. Y. Toler.

Width, 4.1 feet; area, 0.89 square foot; mean velocity, 1.60 feet per second; discharge, 1.42 second-feet.

*Pine Creek near Alturas, Cal.*—This stream is a tributary of South Fork of Pit River. The following measurements were made in flume 100 feet below Gibbins & Mulkey's power house, 7 miles east of the town of Alturas, Cal.

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August 11: Width, 2.2 feet; area, 2.8 square feet; mean velocity, 4.43 feet per second; discharge, 12.4 second-feet.

August 22: Width, 2.15 feet; area, 2.6 square feet; mean velocity, 4.35 feet per second; discharge, 11.3 second-feet.

October 1: Width, 2.3 feet; area, 3.1 square feet; mean velocity, 3.94 feet per second; discharge, 12.2 second-feet.

*Pit River at Lookout, Cal.*—The following measurements were made during 1905 at bridge on county road east of town of Lookout, Cal.

June 13: Width, 87 feet; area, 217 square feet; mean velocity, 0.71 foot per second; discharge, 155 second-feet.

July 7: Width, 67 feet; area, 112 square feet; mean velocity, 0.51 foot per second; discharge, 57 second-feet.

July 20: Width, 40 feet; area, 71 square feet; mean velocity, 0.41 foot per second; discharge, 29 second-feet.

August 19: Width, 8 feet; area, 4.8 square feet; mean velocity, 2.06 feet per second; discharge, 9.9 second-feet.

*Rush Creek near Adin, Cal.*—This stream is a tributary to Ash Creek. The following measurements were made in canyon above upper end of Round Valley north of the town of Alturas, Cal.

July 18: Width, 13 feet; area, 9.7 square feet; mean velocity, 0.56 foot per second; discharge, 5.6 second-feet.

September 22: Width, 9 feet; area, 5.0 square feet; mean velocity, 1.16 feet per second; discharge, 5.8 second-feet.

*Von Loam's ditch near Likely, Cal.*—This ditch diverts water from the South Fork of Pit River. The following measurements were made below head-gate, 2 miles east of the town of Likely, Cal.

June 8: Width, 7.8 feet; area, 16.9 square feet; mean velocity, 2.09 feet per second; discharge, 35 second-feet.

June 20: Width, 8.5 feet; area, 14.9 square feet; mean velocity, 1.68 feet per second; discharge, 25 second-feet.

*Willow Creek near Adin, Cal.*—This stream is tributary to Ash Creek. The following measurements were made at bridge on county road, 5 miles south of the town of Adin, Cal.

July 19: Width, 8 feet; area, 5.2 square feet; mean velocity, 1.09 feet per second; discharge, 5.7 second-feet.

September 21: Width, 8 feet; area, 4.4 square feet; mean velocity, 1.00 foot per second; discharge, 4.4 second-feet.

## STONY CREEK DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Stony Creek drains a portion of the Coast Range and flowing in a northerly direction discharges its waters into the Sacramento River near Orland, Cal. It has numerous tributaries, all of which are torrential in their character. The formation on the higher elevations is of granite with good soil covering and is heavily timbered. In the lower portion of the drainage basin the formation is shale, sandstone, and conglomerate, with heavy growth of brush and grass. This portion of the basin is used extensively for pasturage, the soil being heavy, it packs readily, producing a large per cent of run-off. The mean average rainfall on the higher elevation is about 40 inches; while on the lower reaches it is 20 inches. The precipitation is almost wholly in the form of rain, with some snow on the upper reaches which soon melts and only adds to the flood discharge.

The gaging station on this stream is located near the point where it emerges from the foothills and enters the Sacramento Valley.

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### STONY CREEK NEAR FRUTO, CAL.

This station was established on January 30, 1901, by Burt Cole. It is located at Julian's ranch, 7 miles northwest of Fruto, and 1¾ miles above the proposed mill-site dam.

The channel is straight for 200 feet above and below the cable. The current is very swift at high water and sluggish at low water. Neither bank is subject to overflow, but at high stages of the creek the water spreads to the right for several hundred feet. The bed of the stream is of gravel and is subject to some change.

Discharge measurements are made from a car and cable. The initial point for soundings is the eyebolt on the left bank to which the cable is attached.

The gage is in two sections. During 1905 the gage was read twice each day by W. H. Julian. The bench mark is the head of an iron bolt set in the rock near the upper gage; elevation, 14.00 feet above the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 85, 100, and 134 of the United States Geological Survey.

*Discharge measurements of Stony Creek near Fruto, Cal., in 1905.*

| Date | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| February 16 | O. W. Peterson | 130 | 204 | 3.35 | 5.13 | 684 |
| June 23 | do | 110 | 84 | 1.52 | 3.90 | 128 |
| August 4 | Peterson and Lee | 32 | 23 | 1.22 | 3.30 | 28 |
| September 8 | C. H. Lee | 33 | 32 | .51 | 3.22 | 16.3 |
| September 14 | W. B. Clapp | 33 | 17 | .83 | 3.20 | 14.1 |
| October 4 | Lee and Hawley | 24 | 23 | .76 | 3.24 | 17.6 |



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*Daily gage height, in feet, of Stony Creek near Fruto, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.0 | 10.0 | 5.2 | 6.1 | 4.7 | 4.6 | 3.7 | 3.2 | 3.1 | 3.2 | 3.3 | 3.6 |
| 2 | 6.8 | 8.75 | 5.2 | 6.0 | 5.0 | 4.5 | 3.6 | 3.2 | 3.1 | 3.2 | 3.3 | 3.6 |
| 3 | 6.6 | 7.35 | 5.1 | 6.0 | 5.0 | 4.5 | 3.6 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 4 | 6.3 | 6.7 | 5.1 | 5.9 | 5.0 | 4.6 | 3.6 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 5 | 6.2 | 6.2 | 5.0 | 5.9 | 4.9 | 4.5 | 3.6 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 6 | 6.1 | 6.0 | 5.0 | 5.8 | 4.8 | 4.5 | 3.5 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 7 | 5.0 | 5.8 | 5.0 | 5.8 | 6.3 | 4.4 | 3.5 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 8 | 4.9 | 5.6 | 4.9 | 5.7 | 5.75 | 4.4 | 3.5 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 9 | 4.9 | 5.5 | 4.9 | 5.6 | 5.5 | 4.3 | 3.5 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 10 | 4.8 | 5.4 | 4.9 | 5.5 | 5.5 | 4.3 | 3.5 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 11 | 4.8 | 5.4 | 4.8 | 5.4 | 5.4 | 4.2 | 3.5 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 12 | 4.8 | 5.3 | 6.4 | 5.3 | 5.4 | 4.2 | 3.4 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 13 | 4.7 | 5.3 | 8.25 | 5.3 | 5.3 | 4.2 | 3.4 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 14 | 9.5 | 5.2 | 7.75 | 5.2 | 5.3 | 4.1 | 3.4 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 15 | 7.75 | 5.2 | 8.5 | 5.2 | 5.2 | 4.1 | 3.4 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 16 | 8.5 | 5.1 | 8.5 | 5.3 | 5.2 | 4.1 | 3.3 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 17 | 7.8 | 5.5 | 7.7 | 5.3 | 5.1 | 4.1 | 3.3 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 18 | 7.7 | 5.8 | 7.15 | 5.3 | 5.0 | 4.1 | 3.3 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 19 | 7.4 | 5.7 | 9.25 | 5.2 | 4.9 | 4.0 | 3.3 | 3.2 | 3.2 | 3.2 | 3.3 | 3.6 |
| 20 | 6.8 | 6.0 | 8.25 | 5.2 | 4.9 | 4.0 | 3.3 | 3.1 | 3.2 | 3.2 | 3.3 | 3.6 |
| 21 | 6.8 | 5.8 | 7.3 | 5.0 | 4.8 | 4.0 | 3.3 | 3.1 | 3.2 | 3.2 | 3.3 | 3.6 |
| 22 | 9.75 | 5.6 | 6.75 | 5.0 | 4.8 | 3.9 | 3.3 | 3.1 | 3.2 | 3.2 | 3.3 | 3.6 |
| 23 | 9.25 | 5.5 | 6.55 | 5.0 | 4.7 | 3.9 | 3.3 | 3.1 | 3.2 | 3.2 | 3.3 | 3.6 |
| 24 | 9.5 | 5.4 | 7.25 | 4.9 | 4.7 | 3.9 | 3.3 | 3.1 | 3.2 | 3.3 | 3.3 | 3.6 |
| 25 | 7.7 | 5.4 | 6.6 | 4.9 | 4.6 | 3.8 | 3.3 | 3.1 | 3.2 | 3.3 | 3.4 | 3.6 |
| 26 | 6.9 | 5.3 | 6.55 | 4.9 | 4.9 | 3.8 | 3.3 | 3.1 | 3.2 | 3.3 | 3.4 | 3.6 |
| 27 | 6.45 | 5.3 | 6.3 | 4.8 | 5.25 | 3.8 | 3.3 | 3.1 | 3.2 | 3.3 | 3.4 | 3.8 |
| 28 | 6.3 | 5.2 | 6.1 | 4.8 | 4.8 | 3.7 | 3.3 | 3.1 | 3.2 | 3.3 | 3.4 | 3.8 |
| 29 | 6.1 | ..... | 7.35 | 4.8 | 4.8 | 3.7 | 3.3 | 3.1 | 3.2 | 3.3 | 3.6 | 3.8 |
| 30 | 6.0 | ..... | 6.5 | 4.7 | 4.7 | 3.7 | 3.2 | 3.1 | 3.2 | 3.3 | 3.6 | 3.8 |
| 31 | 6.0 | ..... | 6.15 | ..... | 4.6 | ..... | 3.2 | 3.1 | ..... | 3.3 | ..... | 3.8 |

*Station rating table for Stony Creek near Fruto, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.10 | 10 | 4.50 | 350 | 5.90 | 1,310 | 7.60 | 3,150 |
| 3.20 | 14 | 4.60 | 400 | 6.00 | 1,400 | 7.80 | 3,410 |
| 3.30 | 23 | 4.70 | 450 | 6.10 | 1,490 | 8.00 | 3,690 |
| 3.40 | 34 | 4.80 | 500 | 6.20 | 1,580 | 8.20 | 3,980 |
| 3.50 | 47 | 4.90 | 560 | 6.30 | 1,680 | 8.40 | 4,280 |
| 3.60 | 62 | 5.00 | 620 | 6.40 | 1,780 | 8.60 | 4,600 |
| 3.70 | 80 | 5.10 | 685 | 6.50 | 1,880 | 8.80 | 4,930 |
| 3.80 | 100 | 5.20 | 755 | 6.60 | 1,980 | 9.00 | 5,270 |
| 3.90 | 120 | 5.30 | 830 | 6.70 | 2,090 | 9.20 | 5,630 |
| 4.00 | 150 | 5.40 | 905 | 6.80 | 2,200 | 9.40 | 6,000 |
| 4.10 | 180 | 5.50 | 980 | 6.90 | 2,310 | 9.60 | 6,400 |
| 4.20 | 210 | 5.60 | 1,060 | 7.00 | 2,420 | 9.80 | 6,800 |
| 4.30 | 250 | 5.70 | 1,140 | 7.20 | 2,660 | 10.00 | 7,280 |
| 4.40 | 300 | 5.80 | 1,220 | 7.40 | 2,900 | | |

NOTE.—The above table is based on 22 discharge measurements made during 1903–1905 and is fairly well defined throughout. Above 8.7 feet the table is the same as for 1904.

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*Estimated monthly discharge of Stony Creek near Fruto, Cal., for 1905.*

[Drainage area, 760 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 6,700 | 450 | 2,420 | 148,800 | 3.18 | 3.67 |
| February | 7,280 | 685 | 1,471 | 81,700 | 1.94 | 2.02 |
| March | 5,720 | 500 | 2,050 | 126,000 | 2.70 | 3.11 |
| April | 1,490 | 450 | 870 | 51,770 | 1.14 | 1.27 |
| May | 1,680 | 400 | 675 | 41,500 | .888 | 1.02 |
| June | 400 | 80 | 206 | 12,260 | .271 | .302 |
| July | 80 | 14 | 36.5 | 2,244 | .048 | .055 |
| August | 14 | 10 | 12.4 | 762 | .016 | .018 |
| September | 14 | 10 | 13.7 | 815 | .018 | .020 |
| October | 23 | 14 | 16.3 | 1,002 | .021 | .024 |
| November | 62 | 23 | 27.1 | 1,613 | .036 | .040 |
| December | 100 | 62 | 68.1 | 4,187 | .090 | .104 |
| The year | 7,280 | 10 | 656 | 472,700 | .862 | 11.62 |

## FEATHER RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Feather River drains a portion of the western slope of the Sierra Nevada extending east nearly to the Nevada State line, a distance of about 75 miles and north and south for a distance of from 30 to 40 miles.

The greater portion of the watershed is rough and mountainous and has numerous tributaries which drain the slopes of the higher mountains. The formation in the southern and eastern part of the basin is of granite, with a comparatively deep soil covering. There is also a considerable area composed of lava and other volcanic matter in the northern part of the basin. Numerous meadows and valleys also exist, which tend to maintain a steady flow during the dry season. The soil is generally porous and absorbs the moisture readily. The entire watershed is well covered with a growth of brush and timber, much of which is large enough to make lumbering a profitable industry, with the exception of the meadow lands and valleys, which are used for stock ranges and grazing lands. There are numerous large springs, especially in the lava districts, which supply a more or less steady flow throughout the year. These are especially noticeable on North Fork, where there are perennial springs discharging from 50 to 100 second-feet. There is little artificial storage in the drainage area, and the water used for irrigation in the valleys is taken from the natural flow of the streams.

The mean annual precipitation is probably from 40 to 60 inches and is well distributed over the area. It falls largely in the form of snow, but disappears in the early part of the summer.

### FEATHER RIVER AT OROVILLE, CAL.

This station was established January 1, 1902, by S. G. Bennett. It is located at the northeast edge of the town of Oroville, Cal., where Feather River breaks from the foothills on the western slope of the Sierra Nevada into Sacramento Valley. The drainage area is 3,640 square miles.

The current at the station is sluggish at low water and swift at high water. The channel is rough, rocky, and not subject to much change.

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Discharge measurements at low and ordinary stages were made by means of a cable and boat 500 feet above the wagon bridge. High-water measurements were made by means of floats. In February, 1905, a cable with car was placed about 1,000 feet above the bridge. The cable has a span of about 400 feet. The initial point of soundings is the eyebolt on the left bank.

The original gage was previously placed by the United States Weather Bureau and used by them for a number of years. Readings were taken on this rod and reported by the Weather Bureau when there was danger of an overflow on the lower Feather and Sacramento rivers. On August 11, 1904, a new gage rod was put in. The zero of this rod was placed 2 feet lower than that of the old Weather Bureau rod to avoid negative readings at low stages of the river. This rod is placed at the wagon bridge on the left bank of the stream and is in four sections. Three of the lower sections are bolted to rock, and the fourth section, for registering the flood stages, is nailed to the bridge pier. In December, 1905, a staff gage was placed at the station 50 feet below the cable on the left bank. During 1905 the gage was read by D. G. Page, readings being taken from the gage at the bridge. The bench marks are as follows: (1) A point on rock marked with white paint, one-half the distance from the low-water gage to the high-water gage on the bridge pier; elevation, 12.25 feet. (2) A point on rock marked with white paint, 35 feet southwest of low-water gage; elevation, 14.86 feet. (3) A circle of white paint on the point of a rock 15 feet upstream from the 70-foot mark on the cable; elevation, 5.05 feet. (4) A point on rock marked with white paint, 4 feet downstream from 15-foot mark on cable; elevation, 27.16 feet. The elevations of bench marks Nos. 1 and 2 refer to the datum of the gage at the bridge; elevations of bench marks Nos. 3 and 4 refer to the datum of the gage established in December, 1905.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 85, 100, and 134 of the United States Geological Survey.

*Discharge measurements of Feather River at Oroville, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| February 11 | O. W. Peterson | 281 | 3,424 | 2.22 | 6.45 | 7,618 |
| February 18 | do | 279 | 3,320 | 2.08 | 6.10 | 6,911 |
| May 16 | W. B. Clapp | 281 | 3,728 | 2.28 | 6.65 | 8,509 |
| June 26 | O. W. Peterson | 273 | 2,419 | 1.13 | 2.75 | 2,744 |
| August 1 | Peterson and Lee | 270 | 2,078 | .72 | 1.28 | 1,495 |
| September 2 | C. H. Lee | 268 | 2,005 | .62 | .86 | 1,242 |
| October 7 | Hawley and Lee | 272 | 2,013 | .60 | .90 | 1,210 |
| November 17 | R. S. Hawley | 270 | 1,969 | .62 | .92 | 1,212 |

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*Daily gage height, in feet, of Feather River at Oroville, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10.0 | 9.5 | 6.9 | 8.3 | 7.15 | 5.4 | 2.1 | 1.3 | 0.95 | 1.0 | 1.0 | 1.4 |
| 2 | 8.3 | 11.3 | 6.9 | 8.05 | 7.05 | 5.25 | 2.1 | 1.25 | .9 | 1.0 | 1.0 | 1.35 |
| 3 | 7.4 | 10.25 | 6.95 | 8.15 | 6.95 | 5.2 | 2.1 | 1.25 | .9 | .95 | 1.0 | 1.2 |
| 4 | 6.65 | 9.05 | 7.5 | 8.1 | 6.85 | 5.2 | 2.05 | 1.2 | .9 | .95 | 1.0 | 1.15 |
| 5 | 5.8 | 8.9 | 7.75 | 8.05 | 6.75 | 5.15 | 2.0 | 1.15 | .9 | .95 | .95 | 1.1 |
| 6 | 5.5 | 8.95 | 7.4 | 8.0 | 6.55 | 5.0 | 2.0 | 1.15 | .95 | 1.0 | .95 | 1.0 |
| 7 | 5.5 | 7.85 | 7.0 | 8.0 | 6.45 | 4.95 | 1.95 | 1.15 | .95 | 1.0 | .95 | 1.0 |
| 8 | 5.1 | 7.4 | 6.8 | 8.05 | 6.35 | 4.95 | 1.9 | 1.1 | 1.0 | 1.0 | .95 | .95 |
| 9 | 4.5 | 6.95 | 6.75 | 8.0 | 6.25 | 4.9 | 1.9 | 1.1 | 1.0 | 1.1 | .9 | .95 |
| 10 | 4.2 | 6.7 | 6.6 | 7.9 | 6.15 | 4.8 | 1.85 | 1.05 | 1.0 | 1.05 | .9 | .95 |
| 11 | 3.4 | 6.5 | 6.7 | 7.8 | 6.1 | 4.7 | 1.8 | 1.05 | 1.0 | 1.05 | .85 | .95 |
| 12 | 3.3 | 6.25 | 7.85 | 7.7 | 6.0 | 4.6 | 1.8 | 1.05 | .95 | 1.0 | .85 | 1.0 |
| 13 | 3.2 | 5.9 | 10.25 | 7.5 | 5.85 | 4.45 | 1.75 | 1.05 | .95 | 1.0 | .85 | 1.0 |
| 14 | 10.15 | 5.6 | 9.95 | 7.5 | 5.9 | 4.2 | 1.75 | 1.0 | .9 | .95 | .85 | 1.1 |
| 15 | 10.25 | 5.4 | 9.45 | 7.5 | 6.15 | 4.1 | 1.7 | 1.0 | .9 | .95 | .9 | 1.2 |
| 16 | 7.65 | 5.4 | 8.8 | 7.4 | 6.45 | 3.9 | 1.7 | 1.0 | .9 | .95 | .9 | 1.15 |
| 17 | 5.6 | 6.35 | 8.4 | 7.4 | 6.6 | 3.8 | 1.65 | 1.05 | .85 | .95 | .9 | [a] 1.15 |
| 18 | 5.5 | 6.35 | 8.9 | 7.45 | 6.5 | 3.7 | 1.65 | 1.05 | .85 | .95 | .9 | [a] 1.15 |
| 19 | 7.4 | 6.1 | 12.5 | 7.55 | 6.45 | 3.6 | 1.6 | 1.05 | .85 | 1.0 | .9 | [a] 1.15 |
| 20 | 6.65 | 7.8 | 11.35 | 7.35 | 6.4 | 3.45 | 1.6 | 1.1 | .9 | 1.0 | 1.0 | [a] 1.15 |
| 21 | 7.35 | 8.25 | 11.35 | 6.95 | 6.4 | 3.2 | 1.6 | 1.1 | .9 | 1.0 | 1.4 | [a] 1.1 |
| 22 | 11.8 | 7.75 | 10.95 | 6.7 | 6.3 | 3.15 | 1.55 | 1.1 | .9 | 1.0 | 1.3 | [a] 1.1 |
| 23 | 11.95 | 7.4 | 10.8 | 6.8 | 6.3 | 3.05 | 1.5 | 1.2 | .95 | 1.0 | 1.3 | [a] 1.1 |
| 24 | 10.5 | 7.3 | 10.7 | 6.95 | 6.3 | 3.0 | 1.5 | 1.2 | .95 | 1.0 | 1.25 | 1.1 |
| 25 | 9.8 | 7.2 | 9.95 | 7.15 | 6.25 | 2.9 | 1.5 | 1.1 | .9 | .95 | 1.2 | 1.15 |
| 26 | 8.65 | 7.1 | 9.3 | 7.3 | 6.2 | 2.8 | 1.45 | 1.0 | .9 | .95 | 1.2 | 1.15 |
| 27 | 7.9 | 7.1 | 9.05 | 7.45 | ..... | 2.6 | 1.45 | 1.0 | .9 | .95 | 1.1 | 1.2 |
| 28 | 7.45 | 7.0 | 9.5 | 7.5 | 6.0 | 2.5 | 1.4 | 1.0 | 1.7 | .95 | 1.1 | 1.2 |
| 29 | 7.1 | ..... | 10.65 | 7.4 | 5.95 | 2.4 | 1.4 | .95 | 1.3 | 1.0 | 1.3 | 1.3 |
| 30 | 6.85 | ..... | 10.05 | 7.3 | 5.85 | 2.3 | 1.35 | 1.0 | 1.0 | 1.0 | 1.4 | 1.35 |
| 31 | 6.75 | ..... | 8.95 | ..... | 5.65 | ..... | 1.35 | 1.0 | ..... | 1.0 | ..... | [a] 1.35 |

[a] Estimated.

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*Station rating table for Feather River at Oroville, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.90 | 1,230 | 2.70 | 2,590 | 4.40 | 4,570 | 7.20 | 8,640 |
| 1.00 | 1,295 | 2.80 | 2,690 | 4.50 | 4,700 | 7.40 | 9,000 |
| 1.10 | 1,360 | 2.90 | 2,790 | 4.60 | 4,830 | 7.60 | 9,400 |
| 1.20 | 1,430 | 3.00 | 2,900 | 4.70 | 4,960 | 7.80 | 9,800 |
| 1.30 | 1,500 | 3.10 | 3,010 | 4.80 | 5,090 | 8.00 | 10,260 |
| 1.40 | 1,570 | 3.20 | 3,120 | 4.90 | 5,220 | 8.20 | 10,740 |
| 1.50 | 1,640 | 3.30 | 3,230 | 5.00 | 5,350 | 8.40 | 11,280 |
| 1.60 | 1,710 | 3.40 | 3,340 | 5.20 | 5,630 | 8.60 | 11,780 |
| 1.70 | 1,780 | 3.50 | 3,450 | 5.40 | 5,910 | 8.80 | 12,340 |
| 1.80 | 1,850 | 3.60 | 3,570 | 5.60 | 6,190 | 9.00 | 12,900 |
| 1.90 | 1,925 | 3.70 | 3,690 | 5.80 | 6,470 | 9.50 | 14,400 |
| 2.00 | 2,000 | 3.80 | 3,810 | 6.00 | 6,750 | 10.00 | 16,150 |
| 2.10 | 2,075 | 3.90 | 3,930 | 6.20 | 7,050 | 10.50 | 18,100 |
| 2.20 | 2,155 | 4.00 | 4,050 | 6.40 | 7,350 | 11.00 | 20,100 |
| 2.30 | 2,235 | 4.10 | 4,180 | 6.60 | 7,660 | 11.50 | 22,500 |
| 2.40 | 2,315 | 4.20 | 4,310 | 6.80 | 7,980 | 12.00 | 25,100 |
| 2.50 | 2,400 | 4.30 | 4,440 | 7.00 | 8,300 | 12.50 | 28,100 |
| 2.60 | 2,490 | | | | | | |

NOTE.—The above table is based on 21 discharge measurements made during 1904-5. It is well defined between gage heights 0.85 foot and 8 feet. Above gage height 3.5 feet the table is the same as for 1904.

*Estimated monthly discharge of Feather River at Oroville, Cal., for 1905.*

[Drainage area, 3,640 [a] square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 24,800 | 3,120 | 9,860 | 606,300 | 2.71 | 3.12 |
| February | 21,500 | 5,910 | 9,612 | 533,800 | 2.64 | 2.75 |
| March | 28,100 | 7,660 | 13,560 | 833,800 | 3.72 | 4.29 |
| April | 11,000 | 7,820 | 9,403 | 559,500 | 2.58 | 2.88 |
| May | 8,550 | 6,260 | 7,254 | 446,000 | 1.99 | 2.29 |
| June | 5,910 | 2,235 | 4,098 | 243,800 | 1.13 | 1.26 |
| July | 2,075 | 1,535 | 1,790 | 110,100 | .492 | .567 |
| August | 1,500 | 1,262 | 1,354 | 83,250 | .372 | .429 |
| September | 1,780 | 1,200 | 1,273 | 75,750 | .350 | .390 |
| October | 1,360 | 1,262 | 1,286 | 79,070 | .353 | .407 |
| November | 1,570 | 1,200 | 1,321 | 78,610 | .363 | .405 |
| December | 1,570 | 1,262 | 1,385 | 85,160 | .380 | .438 |
| The year | 28,100 | 1,200 | 5,183 | 3,735,000 | 1.42 | 19.23 |

[a] Revised since previous reports.

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### MISCELLANEOUS MEASUREMENTS IN FEATHER RIVER DRAINAGE BASIN.

The following miscellaneous measurements were made in the Feather River drainage basin during 1905:

*Mohawk Creek near New Mohawk, Cal.*—A measurement was made on this stream on September 10, 1905, just above its junction with Middle Fork of Feather River by H. A. Campbell.

Width, 12.9 feet; area, 16.9 square feet; mean velocity, 1.18 feet per second; discharge, 20 second-feet.

*Middle Fork of Feather River at Mohawk Valley, Cal.*—A measurement was made just above mouth of Mohawk Creek on September 10, 1905, by H. A. Campbell.

Width, 10.0 feet; area, 8.8 square feet; mean velocity, 0.17 foot per second; discharge, 1.5 second-feet.

*Feather River at Prattville, Cal.*—A measurement of this stream was made November 25 at lower end of Big Meadows, 4 miles southeast of Prattville, Cal.

Width, 61 feet; area, 320 square feet; mean velocity, 1.88 feet per second; discharge, 601 second-feet.

*Grizzly Creek near Beckwith, Cal.*—This stream is tributary to Middle Fork of Feather River. A measurement was made December 17 one-half mile above its junction with Middle Fork and about 2½ miles west of the town of Beckwith, Cal.

Width, 4 feet; area, 1.8 square feet; mean velocity, 1.72 feet per second; discharge, 3.1 second-feet.

*Indian Creek near Crescent Mills, Cal.*—This stream is tributary to North Fork of Feather River. A measurement was made December 14 at lower end of Indian Valley, one-half mile below highway bridge on Crescent Mill and Taylorsville road, about 1½ miles below the town of Crescent Mills.

Width, 45 feet; area, 66 square feet; mean velocity 1.15 feet per second; discharge, 76 second-feet.

## YUBA RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Yuba River is a tributary of Feather River, which it enters at Marysville, 30 miles above the junction of Feather and Sacramento rivers. The entire drainage area of this river is about 1,327 square miles, of which about 1,220 square miles are above the gaging station at Smartsville. Its extreme length is about 60 miles, and extreme width 56 miles. In the lower stretches of the river, at the location of the present gaging station and in the valley below, the channel has been filled to a considerable depth with débris from hydraulic mining.

The drainage basin is subdivided into 5 small basins, namely: North Fork, with a drainage area of 491.6 square miles; Middle Fork, with a drainage area of 218 square miles; South Fork, with a drainage area of 360 square miles; Deer Creek, with a drainage area of 89.6 square miles, and Dry Creek, with a drainage area of 105.5 square miles. The latter tributary discharges into the main river about 5 miles below the gaging station. The watershed rises gently in rounded and broken mountains, to the crest of the Sierra Nevada, which at the headwaters of the Yuba has a mean elevation of about 8,200 feet, with peaks rising to a height of 9,100 feet. From Mount Lincoln—a peak common to the watersheds of the Yuba, American, and Truckee rivers—to a point about 2½ miles northeast of Mount Weber, the summit of the Sierra Nevada divides the watershed of Yuba River from that of Truckee River, which discharges into Humboldt Basin. Farther north from Mount Weber there is a secondary crest which divides the watersheds of Yuba and Feather rivers, the watershed of the latter stream reaching farther east to a less elevated divide in which the passes are lower than those of the easterly crest.

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The western and lower portions of the Yuba drainage basin are composed of slate and kindred rock, very much eroded and merging into the gravel and alluvial deposits of the Sacramento Valley. The upper portions of the basin are composed principally of lavas and granites, all deeply eroded, particularly the lavas. A stratum of serpentine traverses the watershed of the Yuba River in a direction generally parallel with the crest of the Sierras. The North Fork rises in lavas which vary much in composition and hardness, but which generally have a deep soil covering, with timber and brush growth. The Middle Fork rises in similar lavas and granite. The main and tributary streams fall rapidly, and their canyons head well up in the mountains. The sides of these canyons are covered with timber and brush, which, with the deep soil, retain the moisture and feed numerous perennial springs. In the case of the North Fork this is particularly noticeable. The forests of its watersheds make a reliable and constant stream. The mean annual precipitation for the basins of North and Middle forks is about 54 inches. Warm rains on soft snow sometimes give high flood discharge, but snow remains on the higher peaks until midsummer. The headwaters of South Fork lie upon a broad granite surface into which the streams have not cut deeply until the main stream reaches a point 16 miles from the summit, where it drops rapidly into a deeply eroded canyon. This part of the basin has a precipitation annually of about 60 inches. The entire drainage area of the Yuba contains nearly 100 small glacial lakes.

### YUBA RIVER NEAR SMARTSVILLE, CAL.

This station was established June 2, 1903, by W. H. Stearns. It is located at what is called "The Narrows," 1 mile from Smartsville, Cal., 18 miles from the Southern Pacific Railroad station at Wheatland, Cal., and 20 miles from Marysville, Cal.

The channel is straight for 200 feet above and 300 feet below the station, and the current is swift at all stages. In the 150 feet above the cable the stream has a fall of 0.2 foot and of 0.9 foot in the 200 feet below. Both banks are high and rocky and are not subject to overflow. The banks widen out considerably just below the station. The bed of the stream is composed of gravel and sand—tailings from hydraulic mining—and is constantly shifting. After the rains of 1904 it was found that the bed of the stream had been lowered for an average depth of 2 feet.

Discharge measurements are made from a car and cable. One auxiliary cable is stretched parallel to and 100 feet upstream from the main cable, and a second one is located 150 feet below the station cable for float measurements. The initial point for soundings is on the left bank at the eyebolt to which the cable is fastened. Frequent discharge measurements are made on account of continual changes of the river bed. These changes, however, do not materially affect discharge measurements for the same gage height.

The gage is in two sections. The lower one is bolted to the rock wall on the left bank of the river and the upper one to the right bank. During 1905 the gage was read once each day by J. R. McKeel. Bench marks were established as follows: (1) A point on a rock marked with white paint, 12 feet upstream and about 15 feet to the left of the right eyebolt; elevation, 39.34 feet. (2) A bolt in shelf of rock marked with white paint, 12 feet from high-water gage on right bank; elevation, 13.75 feet. (3) A bolt in the face of rock 20 feet upstream from the cable on right bank; elevation, 16.60 feet. Elevations refer to the datum of the gage.

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Information in regard to this station is contained in Water-Supply Papers Nos. 81, 100, and 134, United States Geological Survey.

*Discharge measurements of Yuba River near Smartsville, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 20 | J. R. McKeel | 180 | 688 | 5.09 | 6.70 | 3,500 |
| February 12 | do | 175 | 671 | 4.69 | 6.30 | 3,147 |
| February 13 | O. W. Peterson | 178 | 665 | 4.39 | 6.25 | 2,920 |
| February 26 | J. R. McKeel | 180 | 936 | 5.76 | 7.00 | 5,397 |
| March 5 | do | 179 | 836 | 5.40 | 6.60 | 4,512 |
| March 15 | do | 180 | 982 | 6.02 | 6.90 | 5,914 |
| April 8 | do | 170 | 1,060 | 6.56 | 7.00 | 6,959 |
| April 24 | do | 170 | 968 | 6.64 | 6.30 | 6,423 |
| May 4 | do | 180 | 868 | 6.01 | 5.80 | 5,221 |
| May 13 | do | 180 | 864 | 5.94 | 5.50 | 5,132 |
| May 28 | do | 183 | 883 | 6.31 | 5.75 | 5,570 |
| June 4 | do | 180 | 732 | 5.40 | 5.00 | 3,955 |
| June 16 | do | 180 | 652 | 5.09 | 4.50 | 3,318 |
| July 7 | do | 155 | 286 | 3.58 | 2.40 | 1,025 |
| July 20 | do | 74 | 165 | 4.22 | 2.00 | 697 |
| July 29 | do | 73 | 158 | 4.01 | 1.60 | 634 |
| July 31 | O. W. Peterson, C. H. Lee | 76 | 137 | 3.38 | 1.64 | 463 |
| August 7 | J. R. McKeel | 68 | 137 | 3.83 | 1.50 | 525 |
| August 15 | do | 62 | 126 | 3.78 | 1.40 | 476 |
| August 21 | do | 68 | 140 | 3.80 | 1.50 | 532 |
| August 28 | do | 62 | 120 | 3.68 | 1.30 | 442 |
| September 5 | do | 62 | 120 | 3.66 | 1.30 | 439 |
| September 25 | do | 57 | 113 | 3.56 | 1.20 | 402 |
| October 8 | Hawley and Lee | 74 | 115 | 3.43 | 1.45 | 395 |
| October 20 | J. R. McKeel | 66 | 126 | 3.62 | 1.40 | 456 |
| October 30 | do | 66 | 125 | 3.55 | 1.35 | 444 |
| November 9 | do | 63 | 121 | 3.48 | 1.30 | 420 |
| November 16 | do | 63 | 117 | 3.44 | 1.20 | 403 |
| November 23 | do | 63 | 123 | 3.56 | 1.35 | 438 |
| November 30 | do | 150 | 224 | 3.70 | 2.20 | 830 |
| December 6 | do | 70 | 140 | 3.80 | 1.60 | 533 |
| December 13 | do | 68 | 133 | 3.65 | 1.50 | 486 |
| December 29 | do | 84 | 167 | 3.96 | 1.90 | 661 |

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*Daily gage height, in feet, of Yuba River near Smartsville, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9.0 | 7.5 | 6.7 | 7.0 | 6.5 | 5.5 | 2.7 | 1.6 | 1.3 | 1.4 | 1.4 | 2.0 |
| 2 | 8.4 | 9.4 | 6.7 | 7.0 | 6.3 | 5.2 | 2.7 | 1.6 | 1.3 | 1.4 | 1.4 | 1.7 |
| 3 | 7.6 | 8.5 | 6.6 | 7.1 | 6.1 | 5.1 | 2.6 | 1.6 | a1.3 | 1.4 | 1.4 | 1.7 |
| 4 | 7.2 | 7.9 | 6.7 | 7.1 | 5.8 | 5.0 | a2.5 | 1.6 | 1.3 | 1.4 | 1.4 | 1.7 |
| 5 | 6.9 | 8.5 | 6.6 | 7.0 | 5.7 | 4.8 | 2.5 | 1.6 | 1.3 | 1.4 | a1.4 | 1.6 |
| 6 | 6.8 | 7.6 | 6.6 | 7.1 | 5.7 | 4.9 | 2.4 | a1.6 | 1.3 | 1.3 | 1.4 | 1.6 |
| 7 | 6.4 | 7.2 | 6.5 | 7.3 | 5.6 | 5.0 | 2.4 | 1.5 | 1.3 | 1.3 | 1.4 | 1.6 |
| 8 | 6.4 | 7.0 | 6.5 | 7.0 | 6.0 | 4.9 | 2.3 | 1.5 | 1.3 | 1.4 | 1.3 | 1.6 |
| 9 | 6.3 | 6.8 | 6.4 | 6.9 | 6.2 | 4.9 | 2.3 | 1.5 | 1.3 | a1.4 | 1.3 | 1.5 |
| 10 | 6.2 | 6.6 | 6.4 | 6.9 | 5.7 | 4.9 | 2.2 | 1.5 | a1.3 | 1.4 | 1.3 | a1.5 |
| 11 | 6.1 | 6.6 | 6.3 | 6.5 | 5.7 | 5.2 | 2.2 | 1.5 | 1.3 | 1.4 | 1.3 | 1.5 |
| 12 | 6.1 | 6.3 | 6.4 | 6.3 | 5.5 | 5.0 | 2.2 | 1.5 | 1.2 | 1.4 | a1.3 | 1.5 |
| 13 | 6.1 | 6.2 | 7.3 | 6.3 | 5.5 | 5.0 | 2.1 | a1.5 | 1.2 | 1.4 | 1.3 | 1.5 |
| 14 | 8.2 | 6.1 | 7.7 | 6.2 | a5.8 | 4.7 | 2.1 | 1.5 | 1.2 | 1.4 | 1.3 | 1.5 |
| 15 | 7.7 | 6.1 | 6.9 | 6.2 | 6.1 | 4.7 | 2.1 | 1.4 | 1.2 | a1.3 | 1.3 | 1.5 |
| 16 | 7.3 | 6.0 | 6.8 | 6.4 | 6.9 | 4.5 | 2.1 | 1.4 | 1.2 | 1.3 | 1.2 | 1.6 |
| 17 | 6.9 | 7.0 | 6.6 | 6.0 | 7.0 | 4.5 | 2.0 | 1.4 | a1.2 | 1.3 | 1.2 | 1.6 |
| 18 | 6.3 | 7.0 | 7.3 | 7.2 | 6.9 | 4.3 | 2.0 | 1.4 | 1.2 | 1.4 | 1.2 | 2.0 |
| 19 | a6.5 | 6.9 | 11.3 | 6.3 | 6.9 | 4.2 | 2.0 | 1.4 | a1.2 | 1.4 | a1.4 | 2.0 |
| 20 | 6.7 | 8.5 | 8.8 | 6.0 | 6.8 | 4.0 | 2.0 | a1.4 | 1.2 | 1.4 | 1.5 | 2.4 |
| 21 | 7.5 | 7.4 | 9.4 | 6.0 | 7.0 | 3.8 | 1.9 | 1.4 | 1.2 | 1.4 | 1.6 | 2.0 |
| 22 | 10.4 | 7.1 | 8.5 | 6.0 | 6.3 | 3.6 | 1.9 | 1.5 | 1.2 | a1.4 | 1.4 | 1.8 |
| 23 | 10.0 | 6.9 | 7.9 | 6.1 | 6.2 | 3.4 | 1.8 | 1.4 | 1.2 | 1.4 | 1.4 | 1.6 |
| 24 | 8.9 | 6.8 | 8.4 | 6.3 | 6.0 | 3.3 | 1.8 | 1.4 | a1.2 | 1.4 | 1.3 | 1.6 |
| 25 | 8.2 | 6.9 | 8.0 | 6.6 | 6.2 | 3.2 | 1.8 | 1.4 | 1.2 | 1.4 | 1.4 | 1.6 |
| 26 | 7.8 | 7.0 | 8.1 | 7.0 | 6.5 | 3.1 | 1.7 | 1.4 | 1.2 | 1.5 | a1.6 | 1.6 |
| 27 | 7.4 | 6.9 | 8.0 | 7.4 | 5.8 | 3.0 | 1.7 | a1.4 | 1.5 | 1.4 | 1.8 | 1.6 |
| 28 | 7.1 | 6.8 | 7.5 | 7.1 | 5.7 | 2.9 | 1.7 | 1.3 | 1.5 | a1.4 | 1.6 | 1.8 |
| 29 | 6.9 | ..... | 8.4 | 7.0 | 5.6 | 2.8 | 1.6 | 1.3 | 1.4 | a1.4 | 1.8 | 1.9 |
| 30 | 6.8 | ..... | 8.0 | 7.1 | 5.5 | 2.8 | 1.6 | 1.3 | 1.4 | 1.4 | 2.2 | 1.8 |
| 31 | 6.7 | ..... | 7.3 | ..... | 5.5 | ..... | 1.6 | 1.3 | ..... | 1.4 | ..... | 1.8 |

a Gage heights estimated.

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*Daily discharge, in second-feet, of Yuba River near Smartsville, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8,500 | 5,200 | 4,750 | 6,730 | 6,845 | 4,920 | 1,235 | 515 | 435 | 455 | 455 | 710 |
| 2 | 7,000 | 10,050 | 4,750 | 6,730 | 6,440 | 4,395 | 1,235 | 515 | 435 | 455 | 455 | 555 |
| 3 | 5,120 | 7,650 | 4,550 | 7,060 | 6,045 | 4,225 | 1,145 | 515 | 435 | 455 | 455 | 555 |
| 4 | 4,300 | 6,150 | 4,750 | 7,060 | 5,470 | 4,060 | 1,060 | 515 | 435 | 455 | 455 | 555 |
| 5 | 3,750 | 7,680 | 4,512 | 6,850 | 5,285 | 3,745 | 1,060 | 515 | 435 | 455 | 455 | 515 |
| 6 | 3,570 | 5,500 | 4,512 | 7,160 | 5,285 | 3,900 | 980 | 515 | 435 | 435 | 455 | 515 |
| 7 | 2,920 | 4,670 | 4,460 | 7,600 | 5,100 | 4,060 | 980 | 480 | 435 | 435 | 455 | 515 |
| 8 | 2,920 | 4,310 | 4,460 | 6,960 | 5,850 | 3,900 | 905 | 480 | 435 | 455 | 435 | 515 |
| 9 | 2,770 | 3,950 | 4,400 | 6,750 | 6,240 | 3,900 | 905 | 480 | 435 | 455 | 435 | 480 |
| 10 | 2,630 | 3,600 | 4,650 | 6,900 | 5,285 | 3,900 | 835 | 480 | 435 | 455 | 435 | 480 |
| 11 | 2,510 | 3,650 | 4,400 | 6,160 | 5,285 | 4,395 | 835 | 480 | 435 | 455 | 435 | 480 |
| 12 | 2,510 | 3,147 | 4,700 | 5,770 | 4,920 | 4,060 | 835 | 480 | 415 | 455 | 435 | 480 |
| 13 | 2,510 | 2,920 | 6,700 | 5,900 | 4,920 | 4,060 | 770 | 480 | 415 | 455 | 435 | 480 |
| 14 | 6,500 | 2,780 | 7,850 | 5,700 | 5,470 | 3,595 | 770 | 480 | 415 | 455 | 435 | 480 |
| 15 | 5,350 | 2,780 | 5,914 | 5,800 | 6,045 | 3,595 | 770 | 455 | 415 | 435 | 435 | 480 |
| 16 | 4,500 | 2,750 | 5,710 | 6,190 | 7,700 | 3,300 | 770 | 455 | 415 | 435 | 415 | 515 |
| 17 | 3,850 | 4,550 | 5,420 | 5,520 | 7,920 | 3,300 | 710 | 455 | 415 | 435 | 415 | 515 |
| 18 | 2,850 | 4,650 | 6,800 | 8,000 | 7,700 | 3,015 | 710 | 455 | 415 | 455 | 415 | 710 |
| 19 | 3,160 | 4,500 | 17,400 | 6,200 | 7,700 | 2,880 | 710 | 455 | 415 | 455 | 435 | 710 |
| 20 | 3,500 | 8,400 | 10,320 | 5,620 | 7,480 | 2,620 | 710 | 455 | 415 | 455 | 480 | 980 |
| 21 | 5,040 | 5,800 | 11,800 | 5,720 | 7,920 | 2,375 | 650 | 455 | 415 | 455 | 515 | 710 |
| 22 | 12,850 | 5,250 | 9,700 | 5,720 | 6,440 | 2,145 | 650 | 480 | 415 | 455 | 455 | 600 |
| 23 | 11,550 | 4,920 | 8,350 | 6,030 | 6,240 | 1,930 | 600 | 455 | 415 | 455 | 455 | 515 |
| 24 | 8,520 | 4,800 | 9,500 | 6,420 | 5,850 | 1,825 | 600 | 455 | 415 | 455 | 435 | 515 |
| 25 | 6,750 | 5,060 | 8,700 | 7,055 | 6,240 | 1,720 | 600 | 455 | 415 | 455 | 455 | 515 |
| 26 | 5,800 | 5,397 | 8,900 | 7,920 | 6,845 | 1,620 | 555 | 455 | 415 | 480 | 515 | 515 |
| 27 | 4,950 | 5,150 | 8,700 | 8,800 | 5,470 | 1,520 | 555 | 455 | 480 | 455 | 600 | 515 |
| 28 | 4,350 | 4,950 | 7,800 | 8,140 | 5,285 | 1,420 | 555 | 435 | 480 | 455 | 515 | 600 |
| 29 | 4,000 | ..... | 9,720 | 7,920 | 5,100 | 1,325 | 515 | 435 | 455 | 455 | 600 | 650 |
| 30 | 3,820 | ..... | 8,800 | 8,140 | 4,920 | 1,325 | 515 | 435 | 455 | 455 | 835 | 600 |
| 31 | 3,650 | ..... | 7,350 | ..... | 4,920 | ..... | 515 | 435 | ..... | 455 | ..... | 600 |

NOTE.—January 1 to April 24 the daily discharge was obtained indirectly. From April 25 to December 31 the daily discharge was obtained from a rating table based on measurements subsequent to April 24.

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*Estimated monthly discharge of Yuba River near Smartsville, Cal., for 1905.*

[Drainage area, 1,220 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 12,850 | 2,510 | 4,903 | 301,500 | 4.02 | 4.64 |
| February | 10,050 | 2,750 | 5,008 | 278,100 | 4.10 | 4.27 |
| March | 17,400 | 4,400 | 7,107 | 437,000 | 5.83 | 6.72 |
| April | 8,800 | 5,520 | 6,751 | 401,700 | 5.53 | 6.17 |
| May | 7,920 | 4,920 | 6,071 | 373,300 | 4.98 | 5.74 |
| June | 4,920 | 1,325 | 3,101 | 184,500 | 2.54 | 2.83 |
| July | 1,235 | 515 | 782 | 48,080 | .641 | .739 |
| August | 515 | 435 | 471 | 28,960 | .386 | .445 |
| September | 480 | 415 | 429 | 25,530 | .352 | .393 |
| October | 480 | 435 | 453 | 27,850 | .371 | .428 |
| November | 835 | 415 | 474 | 28,200 | .389 | .434 |
| December | 980 | 480 | 566 | 34,800 | .464 | .535 |
| The year | 12,850 | 415 | 3,010 | 2,170,000 | 2.47 | 33.34 |

## MISCELLANEOUS MEASUREMENTS, YUBA RIVER DRAINAGE BASIN.

*Bay Counties Power Company flume near Nevada City, Cal.*—A measurement was made in the flume opposite Purdon bridge over the South Fork of Yuba River on September 3, 1905, by H. A. Campbell.

Width, 6 feet; area, 13.5 square feet; mean velocity, 5.11 feet per second; discharge, 69 second-feet.

*Middle Fork of Yuba River near Nevada City, Cal.*—A measurement was made one-half mile upstream from Freeman's bridge and about 3 miles north of Nevada City on September 4, 1905, by H. A. Campbell.

Width, 22 feet; area, 31 square feet; mean velocity, 2.06 feet per second; discharge, 64 second-feet.

*North Fork of Yuba River near Goodyears bar, Cal.*—A measurement was made on this stream September 5, 1905, from the downstream side of the wagon bridge at Goodyears bar by H. A. Campbell.

Width, 44 feet; area, 96 square feet; mean velocity, 1.54 feet per second; discharge, 149 second-feet.

*North Fork of North Fork of Yuba River near Downieville, Cal.*—This stream enters the North Fork of Yuba River at Downieville, Cal. A measurement was made 1½ miles north of Downieville and 100 yards above its junction with Middle Fork of North Fork on September 6, 1905, by H. A. Campbell.

Width, 10 feet; area, 18.5 square feet; mean velocity, 0.36 foot per second; discharge, 6.7 second-feet.

A measurement was made 30 yards below junction of Middle Fork of North Fork of Yuba River, about 1½ miles north of Downieville, Cal., on September 6, 1905, by H. A. Campbell.

Width, 26 feet; area, 37 square feet; mean velocity, 0.73 foot per second; discharge, 27 second-feet.

*Wheeler flume near Downieville, Cal.*—This flume takes water from the East Fork of the North Fork of Yuba River. A measurement was made on September 6, 1905, at the headgate three-fourths mile north of Downieville by H. A. Campbell.

Width, 3.1 feet; area, 2.3 square feet; mean velocity, 1.91 feet per second; discharge, 4.4 second-feet.

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*Davis ditch near Downieville, Cal.*—This ditch is taken out of East Fork of North Fork of Yuba River about a mile above Downieville. A measurement was made one-half mile below the head-gate on September 6, 1905, by H. A. Campbell.

Width, 3.0 feet; area, 1.9 square feet; mean velocity, 1.47 feet per second; discharge, 2.8 second-feet.

*East Fork of North Fork of Yuba River at Downieville, Cal.*—A measurement was made on September 6, 1905, 10 yards above its junction with North Fork of North Fork of Yuba River at Downieville by H A. Campbell.

Width, 22 feet; area, 29 square feet; mean velocity, 0.59 foot per second; discharge, 17 second-feet.

*North Fork of North Fork of Yuba River at Downieville, Cal.*—A measurement was made on September 6, 1905, on this stream 10 yards above its junction with North Fork of Yuba River by H. A. Campbell.

Width, 28 feet; area, 52 square feet; mean velocity, 0.77 foot per second; discharge, 40 second-feet.

*North Fork of Yuba River at Downieville, Cal.*—A measurement was made from the upstream side of the wagon bridge at Downieville on September 6, 1905, by H. A. Campbell.

Width, 40 feet; area, 184 square feet; mean velocity, 0.76 foot per second; discharge, 139 second-feet.

*South Fork of North Fork of Yuba River near Sierra City, Cal.*—A measurement was made on September 7, 1905, by H. A. Campbell, about one-third of a mile above its junction with the North Fork of the North Fork and about 1¼ miles east of Sierra City.

Width, 2.7 feet; area, 2.5 square feet; mean velocity, 0.68 foot per second; discharge, 1.7 second-feet.

*Mining company's flume near Sierra City, Cal.*—A measurement was made on September 7, 1905, by H. A. Campbell, about 1 mile below heading.

Width, 2.5 feet; area, 2.2 square feet; mean velocity, 4.50 feet per second; discharge, 9.9 second-feet.

*North Fork of North Fork of Yuba River near Sierra City, Cal.*—A measurement was made on September 7, 1905, by H. A. Campbell, about one-half mile above its junction with the South Fork of the North Fork and about 1 mile east of Sierra City.

Width, 25 feet; area, 41 square feet; mean velocity, 0.56 foot per second; discharge, 23 second-feet.

## BEAR RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Bear River drains an area of 287 square miles between the Yuba and American rivers. Its headwaters do not reach back to the crest of the range so that it seldom receives precipitation in the form of lasting snow. It is torrential in character, having no forested areas except in its upper portion. The rainfall records kept by the Central Pacific from Auburn to Emigrant Gap are indicative of the precipitiation in the southern part of its basin. A 28-year record at Grass Valley in the northern portion of its watershed gives a mean of 49.41 inches.

### BEAR RIVER ABOVE WHEATLAND, CAL.

This station was established by O. W. Peterson on October 8, 1904. It is located about 800 feet below McCourtney Crossing and 8 miles above Wheatland.

The channel is straight for 350 feet both above and below the station. At ordinary stages the velocity is moderate. Neither bank is subject to overflow. The bed of the stream is composed of gravel and is not subject to any material change.

Discharge measurements are made from a car and cable. An auxiliary cable is located 150 feet downstream and parallel to the large one, so that float measurements can be made at very high water. The white-oak tree to which the right end of the cable is fastened is the initial point for soundings.

The gage rods are 300 feet above the station, on the left bank of the river. Two of the sections are bolted to the rock and the upper section is nailed to a tree. During 1905 the

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gage was read once each day by Hermann Ernestus. A standard United States Geological Survey bench mark is sulphured in a hole drilled in the rock between the two upper sections of the gage; elevation, 12.26 feet above the datum of the gage.

A description of this station with gage height and discharge data is contained in Water-Supply Paper No. 134, United States Geological Survey.

*Discharge measurements of Bear River above Wheatland, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| February 8 | F. R. S. Buttemer | 142 | 225 | 4.21 | 5.10 | 948 |
| February 13 | do | 140 | 165 | 3.62 | 4.57 | 598 |
| February 19 | do | 139 | 172 | 3.66 | 4.66 | 629 |
| February 24 | do | 139 | 151 | 3.50 | 4.50 | 528 |
| June 27 | O. W. Peterson | 42 | 47 | 1.89 | 3.42 | 89 |
| July 30 | Peterson and Lee | 27 | 39 | .95 | 3.10 | 37 |
| September 3 | C. H. Lee | 31 | 44 | 1.43 | 3.24 | 63 |
| October 10 | Hawley and Lee | 26 | 20 | 2.15 | 3.00 | 43 |

*Daily gage height, in feet, of Bear River above Wheatland, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.0 | 5.6 | 4.3 | a 5.45 | a 4.1 | a 4.1 | 3.2 | 3.1 | 3.2 | 3.1 | 3.1 | 3.4 |
| 2 | 4.8 | 7.0 | 4.2 | 5.3 | a 4.2 | a 4.1 | 3.2 | 3.1 | 3.2 | 3.1 | 3.0 | 3.3 |
| 3 | 4.3 | 4.9 | 4.2 | 5.0 | 4.5 | a 4.1 | 3.2 | 3.1 | 3.2 | 3.1 | 3.0 | 3.2 |
| 4 | 4.2 | 6.7 | 4.2 | 4.9 | 4.2 | a 4.1 | 3.2 | 3.1 | 3.2 | 3.1 | 3.0 | 3.2 |
| 5 | 4.2 | 7.0 | 4.2 | 4.8 | a 4.4 | a 4.1 | 3.2 | 3.1 | 3.4 | 3.1 | 3.0 | 3.2 |
| 6 | 4.1 | 5.5 | 4.2 | 4.7 | a 4.5 | a 4.0 | 3.2 | 3.1 | 3.2 | 3.1 | 3.0 | 3.1 |
| 7 | 4.0 | 5.1 | 4.2 | 4.6 | 4.6 | a 4.0 | 3.1 | 3.1 | 3.2 | 3.1 | 3.0 | 3.1 |
| 8 | 3.9 | 5.2 | 4.1 | 4.5 | a 4.7 | a 3.8 | 3.1 | 3.1 | 3.2 | 3.1 | 3.0 | 3.1 |
| 9 | 4.4 | 5.0 | 4.0 | 4.4 | 4.8 | a 3.8 | 3.1 | 3.1 | 3.2 | 3.1 | 3.0 | 3.1 |
| 10 | 4.2 | 4.8 | 4.0 | 4.4 | a 4.7 | a 3.8 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 |
| 11 | 4.0 | 4.9 | 4.0 | 4.4 | a 4.7 | a 3.8 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 |
| 12 | 3.9 | 4.6 | 4.2 | 4.4 | a 4.7 | a 3.8 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 |
| 13 | 3.8 | 4.5 | 4.7 | 4.3 | a 4.7 | a 3.8 | 3.1 | 3.35 | 3.1 | 3.1 | 2.9 | 3.0 |
| 14 | 5.0 | 4.4 | 4.6 | 4.3 | a 4.7 | a 3.8 | 3.1 | 3.1 | 3.1 | 3.1 | 2.9 | 3.0 |
| 15 | 4.5 | 4.3 | 4.4 | 4.3 | a 5.1 | a 3.8 | 3.2 | 3.4 | 3.1 | 3.1 | 2.9 | 3.0 |
| 16 | 4.8 | 4.7 | 4.4 | 4.5 | a 5.5 | a 3.6 | 3.1 | 3.1 | 3.1 | 3.1 | 2.9 | 3.1 |
| 17 | 4.4 | 5.0 | 4.4 | 4.4 | a 5.5 | a 3.6 | 3.1 | 3.1 | 3.1 | 3.1 | 2.9 | 3.0 |
| 18 | 4.3 | 4.8 | 4.9 | 4.9 | a 5.2 | a 3.6 | 3.2 | 3.1 | 3.0 | 3.1 | 2.9 | 3.0 |
| 19 | 4.9 | 4.7 | 10.5 | 4.9 | a 5.0 | a 3.6 | 3.1 | 3.1 | 3.0 | 3.1 | 2.9 | 3.2 |
| 20 | 4.6 | 5.1 | 6.8 | 4.6 | a 5.0 | a 3.6 | 3.1 | 3.1 | 3.0 | 3.1 | 3.0 | 3.4 |
| 21 | 6.5 | 4.9 | 6.8 | 4.7 | a 4.8 | a 3.6 | 3.1 | 3.1 | 3.0 | 3.1 | 3.1 | 3.3 |
| 22 | 8.5 | 4.7 | 5.9 | 4.7 | a 4.6 | a 3.6 | 3.1 | 3.1 | 3.0 | 3.1 | 3.0 | 3.2 |
| 23 | 7.5 | 4.6 | 5.4 | 4.5 | a 4.5 | a 3.5 | 3.1 | 3.1 | 3.0 | 3.0 | 3.0 | 3.1 |
| 24 | 5.7 | 4.5 | 5.9 | 4.4 | a 4.4 | a 3.5 | 3.1 | 3.1 | 3.0 | 3.1 | 3.0 | 3.0 |
| 25 | 5.2 | 4.5 | 5.3 | 4.3 | a 4.3 | a 3.5 | 3.1 | 3.1 | 3.2 | 3.1 | 3.0 | 3.0 |
| 26 | 5.0 | 4.4 | 5.5 | 4.2 | a 4.3 | a 3.5 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 |
| 27 | 5.8 | 4.4 | 5.7 | a 4.2 | a 4.2 | 3.5 | 3.1 | 3.1 | 3.1 | 3.0 | 3.35 | 3.0 |
| 28 | 5.6 | 4.3 | 5.4 | a 4.2 | a 4.2 | 3.5 | 3.1 | 3.1 | 3.1 | 3.1 | 3.2 | 3.0 |
| 29 | 5.5 | ..... | 7.0 | a 4.1 | a 4.2 | 3.4 | 3.1 | 3.1 | 3.2 | 3.1 | 3.2 | 3.4 |
| 30 | 5.5 | ..... | 6.2 | 4.1 | a 4.2 | 3.3 | 3.1 | 3.3 | 3.1 | 3.1 | 3.5 | 3.2 |
| 31 | 5.8 | ..... | 5.6 | ..... | a 4.2 | ..... | 3.1 | 3.2 | ..... | 3.1 | ..... | 3.5 |

a Estimated.

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*Station rating table for Bear River above Wheatland, Cal., from October 9, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.90 | 10 | 4.10 | 328 | 5.30 | 1,105 | 7.00 | 3,250 |
| 3.00 | 20 | 4.20 | 375 | 5.40 | 1,200 | 7.20 | 3,575 |
| 3.10 | 33 | 4.30 | 425 | 5.50 | 1,300 | 7.40 | 3,910 |
| 3.20 | 49 | 4.40 | 475 | 5.60 | 1,405 | 7.60 | 4,265 |
| 3.30 | 69 | 4.50 | 530 | 5.70 | 1,515 | 7.80 | 4,635 |
| 3.40 | 92 | 4.60 | 585 | 5.80 | 1,625 | 8.00 | 5,020 |
| 3.50 | 118 | 4.70 | 645 | 5.90 | 1,740 | 8.20 | 5,410 |
| 3.60 | 146 | 4.80 | 710 | 6.00 | 1,860 | 8.40 | 5,810 |
| 3.70 | 177 | 4.90 | 780 | 6.20 | 2,105 | 8.60 | 6,220 |
| 3.80 | 210 | 5.00 | 855 | 6.40 | 2,365 | 8.80 | 6,640 |
| 3.90 | 246 | 5.10 | 930 | 6.60 | 2,640 | 9.00 | 7,060 |
| 4.00 | 285 | 5.20 | 1,015 | 6.80 | 2,935 | | |

NOTE.—The above table is based on 11 discharge measurements made during 1904–5. It is well defined between gage heights 3.1 feet and 5.1 feet. Above 6 feet the table is a rough approximation.

*Estimated monthly discharge of Bear River above Wheatland, Cal., for 1904 and 1905.*

[Drainage area, 263 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| 1904. | | | | | | |
| October 9–31 | 7,060 | 92 | 559 | 25,500 | 2.13 | 1.82 |
| November | 1,300 | 92 | 223 | 13,270 | .848 | .946 |
| December | 6,640 | 118 | 504 | 30,990 | 1.92 | 2.21 |
| 1905. | | | | | | |
| January | 6,015 | 210 | 1,058 | 65,060 | 4.02 | 4.64 |
| February | 3,250 | 425 | 975 | 54,150 | 3.71 | 3.86 |
| March | 10,210 | 285 | 1,300 | 79,930 | 4.94 | 5.70 |
| April | 1,250 | 328 | 576 | 34,270 | 2.19 | 2.44 |
| May | 1,300 | 328 | 615 | 37,820 | 2.34 | 2.70 |
| June | 328 | 69 | 193 | 11,480 | .734 | .819 |
| July | 49 | 33 | 37.1 | 2,281 | .141 | .163 |
| August | 92 | 33 | 38.1 | 2,343 | .145 | .167 |
| September | 92 | 20 | 37.3 | 2,220 | .142 | .158 |
| October | 33 | 20 | 32.2 | 1,980 | .122 | .141 |
| November | 118 | 10 | 23.8 | 1,416 | .090 | .100 |
| December | 92 | 20 | 39.8 | 2,447 | .151 | .174 |
| The year | 10,210 | 10 | 410 | 295,400 | 1.56 | 21.06 |

NOTE.—Discharge estimated for missing gage heights.

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### MISCELLANEOUS MEASUREMENTS IN BEAR RIVER DRAINAGE BASIN.

*South Yuba Mining Company's ditch near Colfax, Cal.*—This ditch is taken out of Bear River 2½ miles east of Colfax. A measurement was made September 1, 1905, one-eighth of a mile below this heading in flume, by H. A. Campbell.

Width, 6.0 feet; area, 11.8 square feet; mean velocity, 2.54 feet per second; discharge, 30 second-feet.

*Bear River near Colfax, Cal.*—A measurement was made September 1, 1905, one-eighth of a mile below intake of the South Yuba Mining Company's canal and 2½ miles northeast of Colfax, by H. A. Campbell.

Width, 29 feet; area, 17.8 square feet; mean velocity, 1.45 feet per second; discharge, 26 second-feet.

*Green Horn River near Colfax, Cal.*—A measurement was made 75 yards above the junction of Big Horn and Bear rivers and about 3½ miles north of Colfax on September 1, 1905, by H. A. Campbell.

Width, 10 feet; area, 6.0 square feet; mean velocity, 1.13 feet per second; discharge, 6.8 second-feet.

*Bear River near Colfax, Cal.*—A measurement was made on this stream on September 1, 1905, about 100 yards above mouth of Green Horn River and 3½ miles north of Colfax.

Width, 24 feet; area, 21 square feet; mean velocity, 2.05 feet per second; discharge, 43 second-feet.

## CACHE CREEK DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Cache Creek drains that portion of the eastern slope of the Coast Range directly north from the Puta Creek basin. This basin is long and narrow, extending from northwest to southeast; it has numerous tributaries, of which North Fork is the largest. Most of these tributaries are torrential in their character, but the flow of the main stream is regulated largely by its discharge from Clear Lake, which is fed by numerous creeks having their source in the higher portion of the drainage basin. The lake covers an area of 65 square miles, and has a drainage area of 417 square miles. The streams which enter Cache Creek below Clear Lake are practically dry during the summer months. There are large cultivated areas on the west side of Clear Lake, a greater portion of which is meadow land used for stock raising. There are two gaging stations located on this stream—one at Lower Lake directly at the point where the stream discharges from the lake and one at Yolo a short distance below where it emerges from the foothills. There are numerous diversions above the gaging station at Yolo which take practically the entire flow during the summer months. This water is used for irrigation in the vicinity of Woodland and Yolo, where the soil is rich and deep and susceptible of the highest state of cultivation.

### CLEAR LAKE AT LAKEPORT, CAL.

This station was established in January, 1901. It embraces evaporation for both lake and land. The lake pan is held in place by a triangular raft placed in a protected arm of the lake and anchored in such a manner that it has a clear swing, adjusting itself to the wind so one of its angles will cut the water. The pan is submerged to within an inch or so of the water surface. The land pan is located in a clear open space and set in the ground so that its top is flush with the ground surface, it being protected by a small wire fence that it may not be disturbed. These pans are the regulation type, as referred to in Circular No. 4 of instructions for observing evaporation. The record of this station from January, 1901, to December, 1904, was published in Water-Supply Paper No. 134. The observer is Mr. D. C. Rumsey, at Lakeport, Cal.

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*Evaporation record of Clear Lake at Lakeport, Cal., 1905.*

| Month. | Evaporation in inches. | | Month. | Evaporation in inches. | |
|---|---|---|---|---|---|
| | Lake. | Land. | | Lake. | Land. |
| January | 0.60 | 0.60 | August | 7.25 | 8.45 |
| February | .90 | 1.10 | September | 5.95 | 6.65 |
| March | 1.05 | 1.15 | October | 3.10 | 3.55 |
| April | 2.45 | 2.85 | November | 1.30 | 1.55 |
| May | 3.45 | 3.70 | December | .95 | 1.05 |
| June | 6.50 | 7.00 | | | |
| July | 7.70 | 8.90 | Annual | 41.20 | 46.55 |

### CACHE CREEK AT LOWER LAKE, CAL.

This station was established January 1, 1900, by S. G. Bennett. It is located three-fourths mile from Lower Lake, Cal.

The channel is straight for 150 feet above and 300 feet below the station. The current has a moderate velocity at ordinary stages. The right bank is low, and will overflow at a gage height of about 10 feet. It is covered with a thick growth of willow and oak trees for 100 feet back from the water's edge. The left bank is high and rocky, and is not liable to overflow. The bed of the stream is composed of firm gravel, and changes only slightly: Gravel is sometimes washed in from Siegler Creek 300 feet below the cable.

Discharge measurements are made from a cable 300 feet above the wagon bridge. The initial point for soundings is a small tree in line with the cable on the left bank, 28 feet from the tree to which the cable is attached.

The present gage is a vertical plank nailed to a timber driven into the bed of the river and fastened to a large willow tree on the left bank 100 feet above the cable. On March 25, 1903, when the new gage was put in place, the reading was 5.7 feet. The old gage read 4.4 feet on the same date. During 1905 the gage was read once each day by Mr. J. R. Anderson. The bench mark is a nail in the root of the oak tree, to which cable is fastened on the left bank; elevation, 8.43 feet above the datum of the gage.



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Information in regard to this station is contained in Water-Supply Papers Nos. 81, 85, 100, and 134 of the United States Geological Survey.

*Discharge measurements of Cache Creek at Lower Lake, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 1 | J. R. Anderson | 51 | 138 | 1.86 | 4.10 | 257 |
| January 7 | do | 51 | 146 | 2.05 | 4.20 | 300 |
| January 14[a] | do | 52 | 159 | 2.08 | 4.50 | 331 |
| January 15 | do | 52 | 159 | 2.35 | 4.50 | 373 |
| January 22 | do | 52 | 178 | 2.61 | 4.90 | 467 |
| January 23[a] | do | 56 | 222 | 1.35 | 5.60 | 299 |
| January 24 | do | 52 | 206 | 2.86 | 5.40 | 589 |
| January 26 | do | 53 | 218 | 3.09 | 5.60 | 673 |
| January 31 | do | 53 | 229 | 3.27 | 5.80 | 748 |
| February 1[a] | do | 60 | 273 | 2.06 | 6.48 | 562 |
| February 2[a] | do | 56 | 254 | 3.11 | 6.20 | 790 |
| February 9 | do | 56 | 266 | 3.63 | 6.40 | 965 |
| February 15 | do | 56 | 254 | 3.34 | 6.20 | 848 |
| February 21 | do | 56 | 258 | 3.44 | 6.30 | 888 |
| February 27 | do | 56 | 256 | 3.38 | 6.20 | 864 |
| March 5 | do | 56 | 249 | 3.33 | 6.10 | 828 |
| March 11 | do | 56 | 234 | 3.24 | 5.80 | 757 |
| March 13[a] | do | 60 | 286 | 2.18 | 6.68 | 625 |
| March 14 | do | 56 | 248 | 3.28 | 6.08 | 814 |
| March 20 | do | 59 | 271 | 3.52 | 6.52 | 955 |
| March 25 | do | 60 | 296 | 3.69 | 6.90 | 1,092 |
| March 31 | do | 60 | 308 | 3.76 | 7.10 | 1,159 |
| April 7 | do | 60 | 305 | 3.63 | 7.00 | 1,108 |
| April 15 | do | 56 | 277 | 3.55 | 6.60 | 984 |
| April 22 | do | 56 | 259 | 3.42 | 6.35 | 886 |
| April 29 | do | 56 | 248 | 3.34 | 6.10 | 829 |
| May 6 | do | 56 | 233 | 3.24 | 5.80 | 755 |
| July 11 | O. W. Peterson | 54 | 153 | 2.53 | 4.30 | 387 |
| September 29 | C. H. Lee | 53 | 86 | .93 | 2.83 | 80 |
| October 8 | J. R. Anderson | 48 | 73 | .86 | 2.70 | 63 |
| October 14 | do | 48 | 73 | .82 | 2.70 | 60 |
| October 21 | do | 48 | 68 | .70 | 2.60 | 48 |
| November 5 | do | 48 | 62 | .50 | 2.50 | 31 |
| November 11 | do | 48 | 61 | .46 | 2.45 | 28 |
| November 22 | do | 48 | 58 | .41 | 2.40 | 24 |
| November 27 | do | 48 | 54 | .37 | 2.30 | 20 |

[a] Backwater from Siegler Creek.

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*Daily gage height, in feet, of Cache Creek at Lower Lake, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.1 | 6.5 | 6.2 | 7.3 | 5.9 | 5.3 | 4.5 | 3.8 | 3.25 | 2.8 | 2.5 | 2.5 |
| 2 | 4.1 | 6.2 | 6.15 | 7.1 | 6.0 | 5.3 | 4.5 | 3.8 | 3.2 | 2.8 | 2.5 | 2.5 |
| 3 | 4.15 | 6.25 | 6.15 | 7.05 | 6.0 | 5.25 | 4.45 | 3.75 | 3.2 | 2.8 | 2.5 | 2.45 |
| 4 | 4.2 | 6.25 | 6.1 | 7.0 | 5.95 | 5.25 | 4.4 | 3.75 | 3.2 | 2.8 | 2.5 | 2.45 |
| 5 | 4.2 | 6.35 | 6.1 | 7.0 | 5.90 | 5.2 | 4.4 | 3.7 | 3.2 | 2.8 | 2.5 | 2.45 |
| 6 | 4.2 | 6.4 | 6.1 | 7.0 | 5.8 | 5.2 | 4.4 | 3.7 | 3.15 | 2.8 | 2.5 | 2.4 |
| 7 | 4.2 | 6.4 | 6.05 | 7.0 | 6.05 | 5.15 | 4.4 | 3.7 | 3.15 | 2.75 | 2.45 | 2.4 |
| 8 | 4.2 | 6.4 | 6.0 | 7.0 | 6.0 | 5.15 | 4.4 | 3.7 | 3.15 | 2.75 | 2.45 | 2.4 |
| 9 | 4.2 | 6.4 | 6.0 | 6.9 | 5.9 | 5.1 | 4.35 | 3.7 | 3.1 | 2.75 | 2.45 | 2.4 |
| 10 | 4.2 | 6.4 | 5.9 | 6.8 | 5.85 | 5.1 | 4.35 | 3.7 | 3.1 | 2.7 | 2.45 | 2.35 |
| 11 | 4.2 | 6.3 | 5.8 | 6.8 | 5.8 | 5.05 | 4.3 | 3.65 | 3.1 | 2.7 | 2.45 | 2.35 |
| 12 | 4.2 | 6.3 | 6.2 | 6.85 | 5.8 | 5.0 | 4.3 | 3.65 | 3.05 | 2.7 | 2.45 | 2.35 |
| 13 | 4.3 | 6.3 | 6.45 | 6.75 | 5.8 | 4.95 | 4.25 | 3.65 | 3.05 | 2.7 | 2.4 | 2.35 |
| 14 | 4.5 | 6.3 | 6.2 | 6.6 | 5.75 | 4.95 | 4.25 | 3.6 | 3.05 | 2.7 | 2.4 | 2.35 |
| 15 | 4.5 | 6.2 | 6.2 | 6.65 | 5.75 | 4.9 | 4.2 | 3.6 | 3.05 | 2.7 | 2.4 | 2.45 |
| 16 | 4.7 | 6.2 | 6.3 | 6.55 | 5.8 | 4.9 | 4.15 | 3.6 | 3.0 | 2.7 | 2.4 | 2.45 |
| 17 | 4.75 | 6.3 | 6.4 | 6.45 | 5.7 | 4.85 | 4.15 | 3.55 | 3.0 | 2.65 | 2.4 | 2.35 |
| 18 | 4.75 | 6.3 | 6.3 | 6.4 | 5.7 | 4.85 | 4.1 | 3.55 | 3.0 | 2.65 | 2.4 | 2.45 |
| 19 | 4.8 | 7.0 | 6.6 | 6.5 | 5.7 | 4.8 | 4.1 | 3.5 | 2.95 | 2.6 | 2.4 | 2.5 |
| 20 | 4.8 | 6.3 | 6.55 | 6.3 | 5.6 | 4.8 | 4.1 | 3.5 | 2.95 | 2.6 | 2.5 | 2.5 |
| 21 | 4.9 | 6.3 | 6.7 | 6.35 | 5.6 | 4.75 | 4.05 | 3.5 | 2.9 | 2.6 | 2.35 | 2.45 |
| 22 | 5.85 | 6.35 | 6.8 | 6.35 | 5.5 | 4.75 | 4.05 | 3.45 | 2.9 | 2.6 | 2.4 | 2.4 |
| 23 | 5.55 | 6.35 | 6.8 | 6.3 | 5.5 | 4.75 | 4.0 | 3.45 | 2.9 | 2.6 | 2.25 | 2.5 |
| 24 | 5.7 | 6.3 | 6.95 | 6.25 | 5.5 | 4.7 | 4.0 | 3.45 | 2.9 | 2.6 | 2.3 | 2.5 |
| 25 | 5.65 | 6.25 | 6.95 | 6.25 | 5.45 | 4.7 | 4.0 | 3.4 | 2.9 | 2.6 | 2.3 | 2.5 |
| 26 | 5.65 | 6.25 | 7.1 | 6.2 | 5.4 | 4.65 | 4.0 | 3.4 | 2.9 | 2.6 | 2.35 | 2.5 |
| 27 | 5.75 | 6.2 | 6.95 | 6.2 | 5.4 | 4.6 | 4.0 | 3.35 | 2.9 | 2.6 | 2.3 | 2.45 |
| 28 | 5.8 | 6.2 | 6.75 | 6.15 | 5.4 | 4.6 | 3.95 | 3.35 | 2.85 | 2.55 | 2.65 | 2.4 |
| 29 | 5.8 | ..... | 7.2 | 6.1 | 5.4 | 4.55 | 3.9 | 3.35 | 2.85 | 2.55 | 2.5 | 2.4 |
| 30 | 5.8 | ..... | 7.2 | 6.05 | 5.45 | 4.5 | 3.9 | 3.3 | 2.8 | 2.55 | 2.5 | 2.5 |
| 31 | 5.8 | ..... | 7.1 | ..... | 5.4 | ..... | 3.85 | 3.3 | ..... | 2.5 | ..... | 2.55 |

*Station rating table for Cache Creek at Lower Lake, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.30 | 17 | 3.40 | 149 | 4.50 | 365 | 5.60 | 670 |
| 2.40 | 27 | 3.50 | 163 | 4.60 | 390 | 5.70 | 701 |
| 2.50 | 37 | 3.60 | 178 | 4.70 | 416 | 5.80 | 732 |
| 2.60 | 48 | 3.70 | 194 | 4.80 | 442 | 5.90 | 763 |
| 2.70 | 59 | 3.80 | 212 | 4.90 | 469 | 6.00 | 795 |
| 2.80 | 71 | 3.90 | 232 | 5.00 | 496 | 6.20 | 859 |
| 2.90 | 83 | 4.00 | 252 | 5.10 | 524 | 6.40 | 923 |
| 3.00 | 95 | 4.10 | 274 | 5.20 | 552 | 6.60 | 988 |
| 3.10 | 108 | 4.20 | 296 | 5.30 | 581 | 6.80 | 1,054 |
| 3.20 | 121 | 4.30 | 318 | 5.40 | 610 | 7.00 | 1,120 |
| 3.30 | 135 | 4.40 | 341 | 5.50 | 640 | 7.20 | 1,188 |

NOTE.—The above table is based on 28 discharge measurements made during 1905 and during the latter part of 1904. It is well defined throughout.

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*Estimated monthly discharge of Cache Creek near Lower Lake, Cal., for 1905.*

[Drainage area, 500 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 748 | 274 | 448 | 27,550 | 0.896 | 1.03 |
| February | 1,120 | 562 | 884 | 49,100 | 1.77 | 1.84 |
| March | 1,188 | 610 | 933 | 57,370 | 1.87 | 2.16 |
| April | 1,222 | 811 | 991 | 58,970 | 1.98 | 2.21 |
| May | 811 | 610 | 702 | 43,160 | 1.40 | 1.61 |
| June | 581 | 365 | 476 | 28,320 | .952 | 1.06 |
| July | 365 | 222 | 294 | 18,080 | .588 | .678 |
| August | 212 | 135 | 173 | 10,640 | .346 | .399 |
| September | 128 | 71 | 98.5 | 5,861 | .197 | .220 |
| October | 71 | 37 | 56.0 | 3,443 | .112 | .129 |
| November | 54 | 12 | 30.1 | 1,791 | .060 | .067 |
| December | 42 | 22 | 30.7 | 1,888 | .061 | .070 |
| The year | 1,222 | 12 | 426 | 306,200 | .853 | 11.47 |

### CACHE CREEK NEAR YOLO, CAL.

This station was established January 1, 1903, by S. G. Bennett. It is located at the wagon bridge on the road from Woodland to Yolo, about 1,000 feet above the Southern Pacific Railroad bridge. A new wagon bridge, which greatly improves the channel conditions, was erected during 1904. The station was reestablished on the new bridge December 4, 1904.

Numerous diversions are made from Cache Creek above this station which take practically all of the summer flow. The channel is straight for 1,000 feet above and below the station. The current is swift at ordinary and high stages. The banks are steep and wooded and their height has been increased by levees. They are said to overflow at extreme high water. The bed of the stream is composed of earth and gravel, with a little sand, and is not subject to any material change.

Discharge measurements are made from the downstream side of the bridge. The initial point for soundings is the end of the bridge on the right bank.

The gage is a staff in four sections, three of which are above the bridge and the fourth is bolted to the face of the concrete abutment on the right bank. During 1905 the gage was read by John Woodard. The bench mark is corner of top of concrete abutment to which the high-water section of gage is fastened and directly over gage; elevation, 31.68 feet above the datum of the gage.

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Information in regard to this station is contained in Water-Supply Papers Nos. 100 and 134 of the United States Geological Survey.

*Discharge measurements of Cache Creek near Yolo, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| February 2 | O W. Peterson | 114 | 1,255 | 6.07 | 11.75 | 7,624 |
| February 3 | do | 107 | 833 | 5.83 | 8.30 | 4,860 |
| Do | do | 108 | 890 | 5.87 | 8.80 | 5,227 |
| February 4 | do | 102 | 630 | 6.03 | 7.05 | 3,802 |
| February 15 | do | 94 | 345 | 4.39 | 4.85 | 1,516 |
| May 16 | W. B. Clapp | 91 | 275 | 3.73 | 4.05 | 1,027 |
| June 5 | Peterson and Rodman | 89 | 215 | 3.25 | 3.40 | 699 |
| une 24 | O. W. Peterson | 89 | 151 | 2.37 | 2.60 | 358 |
| August 3 | do | 87 | 88 | 1.47 | 1.79 | 129 |
| September 7 | C. H. Lee | 32 | 19 | .67 | 1.26 | 13.0 |
| September 13 | W. B. Clapp | 17 | 7.3 | .64 | 1.15 | 4.7 |
| October 3 | Lee and Hawley | 2 | .5 | .80 | 1.09 | .4 |

*Daily gage height, in feet, of Cache Creek near Yolo, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.0 | 6.0 | 4.7 | 5.9 | 4.2 | 3.6 | 2.55 | 1.8 | 1.4 | 1.0 |
| 2 | 4.05 | 12.4 | 4.6 | 5.8 | 4.2 | 3.6 | 2.5 | 1.8 | 1.4 | 1.0 |
| 3 | 3.65 | 9.05 | 4.6 | 5.7 | 4.2 | 3.5 | 2.5 | 1.75 | 1.4 | 1.0 |
| 4 | 3.45 | 7.35 | 4.5 | 5.6 | 4.15 | 3.5 | 2.5 | 1.75 | 1.35 | 1.1 |
| 5 | 3.25 | 6.4 | 4.5 | 5.5 | 4.15 | 3.45 | 2.45 | 1.7 | 1.3 | 1.1 |
| 6 | 3.1 | 6.0 | 4.45 | 5.4 | 4.15 | 3.4 | 2.45 | 1.7 | 1.3 | 1.1 |
| 7 | 3.1 | 5.6 | 4.4 | 5.3 | 4.1 | 3.35 | 2.4 | 1.7 | 1.25 | 1.1 |
| 8 | 3.05 | 5.35 | 4.4 | 5.2 | 4.75 | 3.3 | 2.4 | 1.75 | 1.25 | 1.1 |
| 9 | 3.0 | 5.2 | 4.35 | 5.2 | 4.5 | 3.25 | 2.4 | 1.8 | 1.2 | 1.1 |
| 10 | 3.0 | 5.1 | 4.35 | 5.1 | 4.4 | 3.2 | 2.35 | 1.8 | 1.15 | 1.05 |
| 11 | 3.0 | 5.0 | 4.3 | 5.1 | 4.3 | 3.15 | 2.3 | 1.75 | 1.15 | 1.05 |
| 12 | 2.95 | 4.95 | 4.3 | 5.05 | 4.25 | 3.1 | 2.25 | 1.75 | 1.1 | 1.05 |
| 13 | 3.2 | 4.9 | 5.65 | 5.0 | 4.2 | 3.1 | 2.2 | 1.7 | 1.1 | 1.1 |
| 14 | 9.95 | 4.8 | 6.05 | 5.0 | 4.2 | 3.05 | 2.2 | 1.7 | 1.1 | 1.1 |
| 15 | 6.4 | 4.8 | 5.85 | 4.9 | 4.15 | 3.05 | 2.15 | 1.65 | 1.15 | 1.1 |
| 16 | 5.3 | 4.75 | 6.4 | 4.9 | 4.15 | 3.0 | 2.15 | 1.65 | 1.1 | 1.1 |
| 17 | 7.4 | 5.3 | 6.2 | 4.85 | 4.1 | 3.0 | 2.1 | 1.65 | 1.1 | ..... |
| 18 | 7.0 | 5.25 | 5.7 | 4.8 | 4.1 | 3.0 | 2.1 | 1.6 | 1.1 | ..... |
| 19 | 6.55 | 5.2 | 6.0 | 4.75 | 4.1 | 2.95 | 2.0 | 1.6 | 1.15 | ..... |
| 20 | 5.3 | 5.1 | 6.0 | 4.7 | 4.05 | 2.9 | 2.0 | 1.6 | 1.15 | ..... |
| 21 | 5.05 | 5.0 | 5.95 | 4.65 | 4.05 | 2.9 | 1.95 | 1.6 | 1.1 | ..... |
| 22 | 8.25 | 5.0 | 5.9 | 4.6 | 4.0 | 2.85 | 1.9 | 1.65 | 1.1 | ..... |
| 23 | 15.55 | 4.95 | 6.3 | 4.55 | 4.0 | 2.8 | 1.9 | 1.55 | 1.05 | ..... |
| 24 | 8.8 | 4.9 | 6.2 | 4.5 | 3.95 | 2.8 | 1.85 | 1.55 | 1.05 | ..... |
| 25 | 9.25 | 4.85 | 6.1 | 4.45 | 3.95 | 2.75 | 1.8 | 1.55 | 1.05 | ..... |
| 26 | 7.0 | 4.8 | 6.05 | 4.4 | 3.9 | 2.7 | 1.8 | 1.5 | 1.05 | ..... |
| 27 | 6.2 | 4.8 | 6.0 | 4.35 | 3.9 | 2.7 | 1.75 | 1.5 | 1.05 | ..... |
| 28 | 5.8 | 4.7 | 5.9 | 4.3 | 3.8 | 2.65 | 1.75 | 1.5 | 1.05 | ..... |
| 29 | 5.4 | ..... | 7.1 | 4.25 | 3.8 | 2.6 | 1.6 | 1.45 | 1.0 | ..... |
| 30 | 5.15 | ..... | 6.85 | 4.2 | 3.7 | 2.6 | 1.6 | 1.45 | 1.0 | ..... |
| 31 | 5.0 | ..... | 6.1 | ..... | 3.7 | ..... | 1.6 | 1.4 | ..... | ..... |

NOTE.—Creek dry October 17 to December 31.

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*Station rating table for Cache Creek near Yolo, Cal., from January 1, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.00 | 0 | 2.60 | 361 | 4.40 | 1,230 | 7.60 | 3,635 |
| 1.10 | 1 | 2.70 | 395 | 4.60 | 1,350 | 7.80 | 3,815 |
| 1.20 | 7 | 2.80 | 430 | 4.80 | 1,480 | 8.00 | 4,000 |
| 1.30 | 17 | 2.90 | 467 | 5.00 | 1,610 | 8.50 | 4,475 |
| 1.40 | 32 | 3.00 | 505 | 5.20 | 1,745 | 9.00 | 4,970 |
| 1.50 | 53 | 3.10 | 550 | 5.40 | 1,885 | 9.50 | 5,470 |
| 1.60 | 76 | 3.20 | 595 | 5.60 | 2,025 | 10.00 | 5,980 |
| 1.70 | 100 | 3.30 | 640 | 5.80 | 2,170 | 10.50 | 6,505 |
| 1.80 | 125 | 3.40 | 690 | 6.00 | 2,320 | 11.00 | 7,050 |
| 1.90 | 151 | 3.50 | 740 | 6.20 | 2,470 | 11.50 | 7,600 |
| 2.00 | 178 | 3.60 | 790 | 6.40 | 2,625 | 12.00 | 8,150 |
| 2.10 | 206 | 3.70 | 840 | 6.60 | 2,785 | 13.00 | 9,300 |
| 2.20 | 235 | 3.80 | 890 | 6.80 | 2,945 | 14.00 | 10,500 |
| 2.30 | 265 | 3.90 | 945 | 7.00 | 3,110 | 15.00 | 11,700 |
| 2.40 | 296 | 4.00 | 1,000 | 7.20 | 3,280 | 16.00 | 12,950 |
| 2.50 | 328 | 4.20 | 1,110 | 7.40 | 3,455 | | |

NOTE.—The above table is based on 12 discharge measurements made during 1905. It is well defined between gage heights 0 and 5 feet.

*Estimated monthly discharge of Cache Creek near Yolo, Cal., for 1905.*

[Drainage area, 1,280 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 12,390 | 486 | 2,313 | 142,200 | 1.81 | 2.09 |
| February | 8,610 | 1,415 | 2,142 | 119,000 | 1.67 | 1.74 |
| March | 3,195 | 1,170 | 1,969 | 121,100 | 1.54 | 1.78 |
| April | 2,245 | 1,110 | 1,576 | 93,780 | 1.23 | 1.37 |
| May | 1,448 | 840 | 1,058 | 65,050 | .827 | .953 |
| June | 790 | 361 | 542 | 32,250 | .423 | .472 |
| July | 344 | 76 | 214 | 13,160 | .167 | .192 |
| August | 125 | 32 | 86.5 | 5,319 | .068 | .078 |
| September | 32 | 0 | 7.1 | 423 | .0055 | .0061 |
| October | 1 | 0 | .32 | 20 | .00025 | .00029 |
| November | 0 | 0 | 0 | 0 | 0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | 0 |
| The year | 12,390 | 0 | 826 | 592,300 | .645 | 8.68 |

NOTE.—Estimates January 1 to February 10 are subject to considerable error owing to the scouring and filling at this section during high water.

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### MISCELLANEOUS MEASUREMENTS IN CACHE CREEK DRAINAGE BASIN.

*Clover Creek near Upper Lake, Cal.*—This stream discharges into Clear Lake. A measurement was made July 12 by O. W. Peterson, one-third of a mile above town of Upper Lake.

Width, 9.2 feet; area, 5.5 square feet; mean velocity, 0.49 foot per second; discharge, 2.7 second-feet.

*Cole Creek at Kelseyville, Cal.*—This stream discharges into Clear Lake. A measurement was made July 11, 1905, by O. W. Peterson, near Kelseyville and Lower Lake road, three-fourths of a mile below Kelseyville.

Width, 11.5 feet; area, 4.3 square feet; mean velocity, 1.00 foot per second; discharge, 4.3 second-feet.

*Capay ditch at Capay, Cal.*—This ditch diverts water from Cache Creek. The following measurements were made at head of ditch at Capay by O. W. Peterson.

June 19: Width, 18.8 feet; area, 34 square feet; mean velocity, 1.80 feet per second; discharge, 61 second-feet.

August 2: Width, 18.8 feet; area, 21 square feet; mean velocity, 1.57 feet per second; gage-height, 1.10 feet; discharge, 33 second-feet.

*Kelsey Creek near Kelseyville, Cal.*—This stream discharges into Clear Lake. A measurement was made July 11 by O. W. Peterson, 1¼ miles above Kelsey Creek Mill, about 3½ miles above the town of Kelseyville.

Width, 16.5 feet; area, 9 square feet; mean velocity, 1.29 feet per second; discharge, 11.6 second-feet.

*Middle Creek near Upper Lake, Cal.*—This stream discharges into Clear Lake. A measurement was made July 12 by O. W. Peterson, 1½ miles above the town of Upper Lake in sec. 31, T. 15 N, R. 9 W, M. D. M.

Width, 9.9 feet; area, 8.3 square feet; mean velocity, 0.48 foot per second; discharge, 4.0 second-feet.

*Moore's ditch near Woodland, Cal.*—The following measurements were made at Walker Bridge, one-half mile below canal heading:

June 3: Width, 21.6 feet; area, 89 square feet; mean velocity, 0.90 foot per second; discharge, 80 second-feet.

June 3: Width, 20 feet; area, 102 square feet; mean velocity, 1.69 feet per second; discharge, 172 second-feet.

June 17: Width, 24.5 feet; area, 72 square feet; mean velocity, 0.83 foot per second; gage height, 4.20 feet; discharge, 60 second-feet.

June 17: Width, 26 feet; area, 89 square feet; mean velocity, 1.13 feet per second; gage height, 4.80 feet; discharge, 101 second-feet.

June 17: Width, 35 feet; area, 119 square feet; mean velocity, 1.36 feet per second; gage height, 5.55 feet; discharge, 162 second-feet.

June 21: Width, 25.2 feet; area, 74 square feet; mean velocity, 1.65 feet per second; gage height, 5.45 feet; discharge, 122 second-feet.

August 2: Width, 19.8 feet; area, 87 square feet; mean velocity, 1.14 feet per second; gage height, 4.40 feet; discharge, 99 second-feet.

## AMERICAN RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

American River drains an area of about 2,000 square miles of the western slope of the Sierra Nevada. This drainage basin lies between those of the Bear and Yuba rivers on the north and that of Consumnes River on the south. It has three main forks, heading in the summit of the range, which reaches an elevation of about 9,000 feet. The country lying between these main forks is drained by numerous small tributaries. The formation in the higher and greater portions of this basin is of granite, with a considerable timber

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growth. The flow is rather torrential during the winter months, due to the large area of barren and sparsely timbered country in the lower portion of the watershed. The precipitation on the higher elevations is in the form of snow, which usually melts late in the spring. Rainfall records have been kept along the line of the Central Pacific Railroad, which follows the ridge to the north of North Fork.

The mean annual rainfall at Auburn is 33.40 inches, that at Colfax 47.4 inches, and at Cisco and Emigrant Gap about 50 inches. At Georgetown, between North and Middle forks, a 30-year record has an average of 56.72 inches, and at Placerville, above South Fork, another of about the same length shows 43.58 inches.

There are several small lakes in the upper reaches of this basin, the storage capacity of a few having been increased by the construction of low dams at their outlets. This stored water is used for mining purposes during the low-water flow and is used entirely within the drainage basin.

### AMERICAN RIVER NEAR FAIROAKS, CAL.

This station was established November 3, 1904, by O. W. Peterson. It is located at Fairoaks Bridge, near Fairoaks.

The channel is straight for 400 feet above and below the station. At ordinary stages the velocity is sluggish. The right bank is not subject to overflow. At times of very high water the left bank is subject to overflow and a second channel is formed. The bed of the stream is composed of gravel, and is subject to slight changes at times of high water. At ordinary stages the river is about 210 feet in width and averages over 4 feet in depth.

Discharge measurements are made from the downstream side of the bridge. The vertical face of the right abutment is 4 feet from the initial point for soundings.

The gage is a staff nailed to one of the piles at the upper side at the right end of Fairoaks Bridge. During 1905 the gage was read twice each day by W. F. Bailey, jr. The bench mark is a nail driven in the guard rail over the upstream center pier; elevation, 31.00 feet above the datum of the gage.

A description of this station, with gage height and discharge data, is contained in Water-Supply Paper No. 134 of the United States Geological Survey.

*Discharge measurements of American River near Fairoaks, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 26 | F. R. S. Buttemer | 356 | 1,648 | 2.41 | 4.52 | 3,971 |
| January 26 | do | 356 | 1,648 | 2.42 | 4.49 | 3,994 |
| February 2 | do | 373 | 2,891 | 4.35 | 7.55 | 12,580 |
| February 11 | do | 353 | 1,505 | 2.09 | 4.08 | 3,151 |
| February 17 | do | 354 | 1,544 | 2.19 | 4.22 | 3,378 |
| February 22 | do | 355 | 1,776 | 2.67 | 4.90 | 4,742 |
| May 17 | W. B. Clapp | 370 | 2,864 | 4.34 | 7.35 | 12,340 |
| June 28 | O. W. Peterson | 260 | 993 | 1.53 | 2.88 | 1,520 |
| July 29 | Peterson and Lee | 167 | 694 | .56 | 1.46 | 392 |
| September 4 | C. H. Lee | 165 | 599 | .20 | .88 | 119 |

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*Daily gage height, in feet, of American River near Fairoaks, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.1 | 4.25 | 4.6 | 5.95 | 6.0 | 4.6 | 2.85 | 1.4 | 0.9 | 0.95 | 0.95 | 1.35 |
| 2 | 5.25 | 7.6 | 4.6 | 6.15 | 6.1 | 4.55 | 2.75 | 1.4 | .9 | .9 | .95 | 1.25 |
| 3 | 3.95 | 5.85 | 4.6 | 5.95 | 5.9 | 4.45 | 2.7 | 1.4 | .9 | .95 | .95 | 1.2 |
| 4 | 3.65 | 5.05 | 4.55 | 6.0 | 5.6 | 4.55 | 2.7 | 1.4 | .9 | .95 | .95 | 1.25 |
| 5 | 3.5 | 6.65 | 4.6 | 6.15 | 5.55 | 4.45 | 2.65 | 1.35 | .85 | .95 | .95 | 1.1 |
| 6 | 3.35 | 5.5 | 4.6 | 6.0 | 5.5 | 5.1 | 2.6 | 1.35 | .9 | .95 | .95 | 1.15 |
| 7 | 3.6 | 4.9 | 4.6 | 6.15 | 5.6 | 5.15 | 2.5 | 1.35 | .9 | .95 | .95 | 1.2 |
| 8 | 3.6 | 4.45 | 4.6 | 5.75 | 5.55 | 5.2 | 2.5 | 1.35 | .9 | .9 | .95 | 1.15 |
| 9 | 3.9 | 4.25 | 4.5 | 5.65 | 5.8 | 5.35 | 2.4 | 1.3 | .85 | .95 | .95 | 1.15 |
| 10 | 3.1 | 4.2 | 4.3 | 5.8 | 5.5 | 4.6 | 2.3 | 1.3 | .9 | .9 | 1.0 | 1.15 |
| 11 | 3.0 | 4.1 | 4.45 | 5.5 | 5.2 | 4.7 | 2.2 | 1.3 | .9 | .95 | 1.0 | 1.0 |
| 12 | 3.0 | 4.05 | 4.6 | 5.65 | 5.2 | 4.6 | 2.15 | 1.3 | .85 | .95 | 1.0 | 1.0 |
| 13 | 2.95 | 3.85 | 4.8 | 4.85 | 5.0 | 4.35 | 2.05 | 1.3 | .9 | .95 | 1.0 | .9 |
| 14 | 3.5 | 3.7 | 5.1 | 5.25 | 5.55 | 4.1 | 2.0 | 1.25 | .9 | .95 | .95 | .95 |
| 15 | 4.65 | 3.6 | 5.15 | 5.1 | 6.15 | 4.2 | 1.9 | 1.25 | .9 | 1.0 | .95 | 1.0 |
| 16 | 4.55 | 3.4 | 4.55 | 4.85 | 6.7 | 4.0 | 1.8 | 1.25 | 1.0 | .95 | 1.0 | 1.1 |
| 17 | 3.9 | 4.35 | 4.75 | 4.7 | 6.95 | 3.85 | 1.8 | 1.25 | .95 | .95 | 1.05 | 1.1 |
| 18 | 3.85 | 4.25 | 4.9 | 4.55 | 6.65 | 3.8 | 1.7 | 1.25 | 1.0 | .95 | .9 | 1.15 |
| 19 | 3.95 | 4.15 | 10.5 | 4.65 | 6.5 | 3.8 | 1.65 | 1.2 | .9 | .95 | 1.0 | 1.2 |
| 20 | 3.9 | 6.15 | 7.45 | 4.9 | 6.4 | 3.8 | 1.6 | 1.2 | .95 | .95 | 1.05 | 1.1 |
| 21 | 4.1 | 5.2 | 7.1 | 5.4 | 5.95 | 3.85 | 1.55 | 1.2 | .95 | .95 | 1.0 | 1.05 |
| 22 | 4.8 | 4.85 | 6.7 | 6.5 | 5.3 | 3.55 | 1.5 | 1.2 | .9 | .95 | 1.15 | 1.05 |
| 23 | 6.85 | 4.6 | 6.1 | 7.4 | 5.5 | 3.7 | 1.5 | 1.2 | .95 | .95 | 1.0 | 1.2 |
| 24 | 6.4 | 4.5 | 6.55 | 8.85 | 5.7 | 3.3 | 1.5 | 1.1 | .95 | .95 | 1.15 | 1.3 |
| 25 | 5.4 | 4.55 | 6.3 | 7.65 | 6.1 | 3.15 | 1.45 | 1.1 | .9 | 1.0 | 1.0 | 1.2 |
| 26 | 4.45 | 4.9 | 6.5 | 7.1 | 5.9 | 3.1 | 1.45 | 1.1 | .9 | .95 | 1 1 | 1.3 |
| 27 | 4.25 | 4.7 | 6.8 | 6.6 | 5.5 | 2.9 | 1.45 | 1.1 | .95 | .95 | 1.0 | 1.4 |
| 28 | 3.9 | 4.75 | 6.4 | 6.7 | 5.35 | 2.8 | 1.45 | 1.0 | .95 | 1.0 | 1.4 | 1.4 |
| 29 | 3.8 | ..... | 6.85 | 6.8 | 4.75 | 2.75 | 1.45 | 1.0 | .95 | .95 | 1.75 | 1.55 |
| 30 | 3.75 | ..... | 6.35 | 6.75 | 4.5 | 2.7 | 1.4 | 1.0 | .95 | .95 | 1.5 | 1.7 |
| 31 | 3.85 | ..... | 5.95 | ..... | 4.15 | ..... | 1.4 | 1.0 | ..... | ..... | ..... | 1.45 |

NOTE.—Gage heights estimated July 2-28; July 30 to September 2; November 1-9.

*Station rating table for American River near Fairoaks, Cal., from November 4 to December 31, 1904.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.40 | 700 | 2.70 | 990 | 3.00 | 1,300 | 3.30 | 1,680 |
| 2.50 | 790 | 2.80 | 1,090 | 3.10 | 1,410 | | |
| 2.60 | 890 | 2.90 | 1,190 | 3.20 | 1,540 | | |

NOTE.—The above table is based on 2 discharge measurements made during 1904, and on the 1905 curve.

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*Station rating table for American River near Fairoaks, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.80 | 90 | 2.20 | 840 | 3.60 | 2,410 | 6.00 | 7,450 |
| 0.90 | 120 | 2.30 | 920 | 3.70 | 2,555 | 6.20 | 8,040 |
| 1.00 | 155 | 2.40 | 1,005 | 3.80 | 2,705 | 6.40 | 8,670 |
| 1.10 | 195 | 2.50 | 1,095 | 3.90 | 2,860 | 6.60 | 9,340 |
| 1.20 | 240 | 2.60 | 1,195 | 4.00 | 3,020 | 6.80 | 10.040 |
| 1.30 | 285 | 2.70 | 1,300 | 4.20 | 3,365 | 7.00 | 10,770 |
| 1.40 | 335 | 2.80 | 1,410 | 4.40 | 3,730 | 7.20 | 11,530 |
| 1.50 | 390 | 2.90 | 1,525 | 4.60 | 4,115 | 7.40 | 12,310 |
| 1.60 | 445 | 3.00 | 1,640 | 4.80 | 4,520 | 7.60 | 13,090 |
| 1.70 | 505 | 3.10 | 1,760 | 5.00 | 4,950 | 7.80 | 13,890 |
| 1.80 | 565 | 3.20 | 1,880 | 5.20 | 5,405 | 8.00 | 14,700 |
| 1.90 | 630 | 3.30 | 2,005 | 5.40 | 5,880 | | |
| 2.00 | 695 | 3.40 | 2,135 | 5.60 | 6,375 | | |
| 2.10 | 765 | 3.50 | 2,270 | 5.80 | 6,900 | | |

NOTE.—The above table is based on 10 discharge measurements made during 1905. It is fairly well defined between gage heights 0.8 foot and 5 feet.

*Estimated monthly discharge of American River near Fairoaks, Cal., for 1904 and 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| 1904. | | | | |
| November 4-30 | 1,355 | 700 | 896 | 47,980 |
| December | 13,600 | 700 | 1,404 | 86,330 |
| 1905. | | | | |
| January | 10,220 | 1,582 | 3,549 | 218,200 |
| February | 13,090 | 2,135 | 4,630 | 257,100 |
| March | 25,900 | 3,545 | 6,924 | 425,700 |
| April | 18,300 | 4,018 | 7,736 | 460,300 |
| May | 10,580 | 3,278 | 6,717 | 413,000 |
| June | 5,760 | 1,300 | 3,231 | 192,300 |
| July | 1,468 | 335 | 719 | 44,210 |
| August | 335 | 155 | 255 | 15,680 |
| September | 155 | 105 | 126 | 7,498 |
| October | 155 | 120 | 138 | 8,485 |
| November | 535 | 120 | 181 | 10,770 |
| December | 505 | 120 | 242 | 14,880 |
| The year | 25,900 | 105 | 2,874 | 2,068,000 |

## MISCELLANEOUS MEASUREMENTS IN AMERICAN RIVER DRAINAGE BASIN.

*South Fork of American River near Placerville, Cal.*—A measurement was made August 20, 1905, at Chillie Bar, 3 miles north of Placerville and 400 yards upstream from wagon bridge, by H. A. Campbell. The distance to water surface from top of outer bar, of lower chord in the middle panel, on the upstream side of bridge was 23.5 feet.

Width, 28 feet; area, 42 square feet; mean velocity, 1.80 feet per second; discharge, 76 second-feet.

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*North Fork of the American River near Auburn, Cal.*—A measurement was made about 400 yards above junction of North and Middle forks and about 2 miles northeast of Auburn on August 21, 1905, by H. A. Campbell.

Width, 28 feet; area, 44 square feet; mean velocity, 1.48 feet per second; discharge, 65 second-feet.

*Middle Fork of the American River near Auburn, Cal.*—A measurement was made on this stream about 400 yards above junction of the North and Middle forks and about 2 miles northeast of Auburn, Cal., on August 21, 1905, by H. A. Campbell.

Width, 55 feet; area, 101 square feet; mean velocity, 0.97 foot per second; discharge, 98 second-feet.

*El Dorado ditch.*—This ditch is taken out of South Fork of the American River about 1 mile below Slippery Ford. A measurement was made at the heading on August 24, 1905, by H. A. Campbell.

Width, 13.9 feet; area, 45 square feet; mean velocity, 1.24 feet per second; discharge, 56 second-feet.

*Silver Fork of American River.*—This stream enters South Fork of American River about 1 mile below Slippery Ford. A measurement was made on August 24, 1905, just above mouth, by H. A. Campbell.

Width, 11 feet; area, 18.3 square feet; mean velocity, 1.07 feet per second; discharge, 19.6 second-feet.

*South Fork of American River.*—A measurement was made one-fourth of a mile above Silver Fork and three-fourths mile below Slippery Ford on August 25, 1905, by H. A. Campbell.

Width, 26 feet; area, 63 square feet; mean velocity, 0.54 foot per second; discharge, 34 second-feet.

*South Fork of Silver Creek.*—A measurement was made on this stream August 26, 1905, about 200 feet above the mouth by H. A. Campbell.

Width, 16.5 feet; area, 21 square feet; mean velocity, 0.30 foot per second; discharge, 6.3 second-feet.

*Silver Creek.*—A measurement was made August 26, 1905, 100 feet above the mouth of South Fork of Silver Creek by H. A. Campbell.

Width, 11 feet; area, 16.2 square feet; mean velocity, 0.92 foot per second; discharge, 14.9 second-feet.

## PUTA CREEK DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Puta Creek drains a portion of the eastern slope of the Coast Range, its waters discharging into Sacramento River through what is known as the Yolo basin in the vicinity of Davis, Cal. This basin is rather long and narrow, extending from west to east; it has numerous tributaries which have a heavy flood discharge during the winter months, but are practically dry during the summer. This stream is torrential in its flow. It has a comparatively small drainage basin with an exceptionally heavy rainfall, especially on the higher elevations in the vicinity of Mount St. Helena. A five-year rainfall record at Helen Mine on the northern slope of Mount St. Helena gives an average of 99.52 inches. The precipitation decreases as we approach the lower elevations. The upper reaches of this basin are well timbered, but the lower portion is comparatively barren of timber, though it has a considerable growth of brush extending to a point where the stream leaves the foothills. The areas in the lower portion of the basin are used principally for pasturage. The topography of the country is rough and precipitous. The underlying rock is an impervious slate and serpentine with a thin soil covering. There is comparatively little tilled land in this drainage basin above the point where the stream emerges from the foothills at Winters. Below this point the soil is deep and susceptible to high cultivation, and at present is used for the raising of grain and fruit.

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### PUTA CREEK NEAR GUENOC, CAL.

This station was established February 12, 1904. It is located about 2 miles below the old town of Guenoc, near the Asbill ranch house and at the Guenoc dam site. The nearest post-office is at Middletown, Cal.

The bed of the stream is gravelly, with a few bowlders above and below the section. Bed rock is laid bare on the right side of the channel. The left bank is high and rocky, while the right bank is rather low and flat and subject to overflow in very high water. The velocity is moderate for ordinary stages of flow, but high in flood periods. The range is about 12 feet, representing discharges of from 7 to 17,000 second-feet. The channel is straight for several hundred feet upstream, but has several large bowlders in it. Downstream it is straight for about 100 feet. The section is located in a narrow gorge at the lower end of a long, flat valley, which is flooded during high water. The channel will not allow the water to run off through the gorge fast enough to prevent backwater forming during flood periods.

Meter measurements during high water are made from a car and cable. At first the cable was located directly opposite the ranch house, but as the location proved very unfavorable it was moved November 15, 1904, to a point about 1,000 feet below. It now has a clear span of about 200 feet. The initial point for soundings is the eyebolt to which the cable is fastened on the left bank. An auxiliary cable has been placed parallel to the large one, so that float measurements can be made in time of very high water. During low water measurements are made by wading.

The gage, which was established near the old section, is still read, although a new one was placed near the cable in its present position. The old gage is a staff in two sections, both being fastened to trees. The section which is read in low water is about 600 feet upstream from the ranch stable, and the high-water section is directly opposite the stable. The new rod is made similarly to the other one. Both sections are located a few feet above the cable. One is bolted to a large bowlder on the left bank and the other nailed to a tree on the right bank. During 1905 the gage was read once each day during ordinary stages and twice a day during high water by Miss Agnes Asbill. The bench mark is the top of the rock to which the low-water section of the new gage is fastened; elevation, 7.62 feet above the datum of the new gage.

A description of this station and gage height and discharge data are contained in Water-Supply Paper No. 134, United States Geological Survey.

*Discharge measurements of Puta Creek near Guenoc, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 1 | F. R. S. Buttemer | 81 | 433 | 1.37 | 5.58 | 592 |
| January 1 | do | 76 | 390 | 1.36 | 5.42 | 530 |
| January 2 | do | 66 | 342 | 1.13 | 5.14 | 386 |
| January 2[a] | do | 66 | 321 | 1.12 | 5.12 | 359 |
| January 3 | do | 66 | 322 | 0.90 | 4.94 | 289 |
| January 4 | do | 64 | 316 | 0.78 | 4.82 | 247 |
| January 14 | do | 110 | 624 | 2.94 | 7.04 | 1,834 |
| January 15 | do | 95 | 478 | 1.83 | 5.96 | 876 |
| January 16 | do | 94 | 429 | 2.04 | 5.86 | 875 |
| January 16 | do | 95 | 467 | 2.08 | 5.98 | 972 |
| July 8 | O. W. Peterson | 16 | 12 | 1.58 | 3.72 | 19 |
| September 29 | C. H. Lee | 8 | 4.1 | 1.66 | 3.56 | 6.8 |

[a] Float measurement.

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*Daily gage height, in feet, of Puta Creek near Guenoc, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.8 | 7.0 | 4.5 | 5.2 | 4.3 | a4.0 | 3.6 | 3.6 | 3.6 | 3.7 | 3.6 | 3.6 |
| 2 | a6.0 | 6.5 | 4.4 | 5.2 | 4.3 | 4.0 | 3.7 | 3.6 | 3.6 | 3.7 | 3.6 | 3.6 |
| 3 | a5.4 | 6.2 | 4.3 | 5.2 | 4.3 | 3.9 | 3.7 | 3.6 | 3.6 | 3.7 | 3.6 | 3.6 |
| 4 | 4.8 | 6.0 | 4.2 | 5.1 | 4.4 | 5.4 | 3.7 | 3.6 | 3.6 | 3.7 | 3.6 | 3.6 |
| 5 | 4.7 | 6.3 | 4.4 | 5.1 | 4.3 | 5.6 | 3.7 | 3.6 | 3.6 | 3.7 | 3.6 | 3.6 |
| 6 | 4.4 | 6.0 | 4.4 | 5.1 | 4.3 | 5.0 | 3.7 | 3.6 | 3.6 | 3.7 | 3.6 | 3.6 |
| 7 | 4.4 | 5.8 | 4.3 | a5.0 | 5.0 | 4.2 | 3.7 | 3.6 | 3.6 | 3.7 | 3.6 | 3.6 |
| 8 | 4.5 | 5.5 | 4.3 | 5.0 | 5.2 | 4.2 | 3.7 | 3.6 | a3.6 | 3.7 | 3.6 | 3.6 |
| 9 | 4.7 | 5.4 | 4.2 | 5.1 | 4.8 | 4.1 | 3.7 | 3.6 | 3.6 | 3.7 | 3.6 | 3.6 |
| 10 | 4.6 | 5.1 | 4.2 | 5.1 | 4.6 | 4.1 | 3.7 | a3.6 | 3.6 | 3.7 | 3.6 | 3.6 |
| 11 | 4.5 | 5.0 | 4.2 | 5.0 | 4.4 | 4.0 | 3.7 | 3.6 | 3.6 | 3.7 | 3.6 | 3.6 |
| 12 | 4.5 | 4.9 | 4.5 | 5.0 | 4.4 | 4.0 | 3.7 | 3.6 | a3.6 | 3.7 | 3.6 | 3.6 |
| 13 | 6.1 | 4.8 | 5.5 | 5.0 | 4.4 | 3.9 | 3.7 | 3.6 | 3.6 | 3.7 | 3.6 | 3.6 |
| 14 | 7.45 | 4.7 | 6.5 | 5.0 | 4.4 | 3.9 | 3.7 | 3.5 | 3.6 | 3.7 | 3.6 | 3.6 |
| 15 | 5.9 | 4.6 | 6.0 | 5.1 | 4.3 | 3.9 | 3.6 | 3.5 | 3.6 | a3.7 | 3.6 | 3.7 |
| 16 | 5.9 | 4.9 | 6.2 | 5.2 | 4.3 | 3.9 | 3.6 | 3.5 | 3.6 | 3.7 | 3.6 | 3.8 |
| 17 | 4.4 | 5.1 | 6.0 | 5.2 | 4.3 | 3.9 | 3.6 | 3.5 | 3.6 | 3.7 | 3.6 | 3.8 |
| 18 | 4.5 | 5.4 | 6.5 | 5.1 | 4.2 | 3.8 | 3.6 | 3.5 | a3.6 | 3.7 | 3.6 | 3.8 |
| 19 | 6.45 | 6.3 | 6.85 | 5.0 | 4.2 | 3.8 | 3.5 | 3.5 | 3.6 | 3.7 | 3.6 | 3.8 |
| 20 | 5.4 | 6.0 | 6.1 | 4.9 | 4.2 | 3.8 | 3.5 | 3.6 | 3.6 | 3.7 | 3.6 | 3.8 |
| 21 | 6.8 | 5.9 | 5.9 | 4.9 | 4.2 | 3.8 | 3.5 | a3.6 | 3.6 | 3.6 | 3.6 | 3.7 |
| 22 | 13.5 | 5.7 | 5.8 | 4.8 | 4.1 | 3.8 | 3.5 | 3.6 | 3.6 | 3.6 | 3.6 | 3.7 |
| 23 | 8.9 | 5.4 | 5.8 | 4.8 | 4.1 | 3.8 | 3.5 | 3.6 | 3.6 | 3.6 | 3.6 | 3.7 |
| 24 | 7.2 | 5.2 | 5.7 | 4.7 | 4.1 | 3.8 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 4.0 |
| 25 | 6.7 | 5.0 | 5.4 | 4.6 | 4.1 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 4.1 |
| 26 | 6.0 | 4.8 | 5.0 | 4.5 | 4.0 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.9 |
| 27 | 5.9 | 4.7 | 5.8 | 4.4 | 4.0 | 3.7 | a3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.9 |
| 28 | 5.7 | 4.6 | 5.8 | 4.3 | 4.0 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | a3.9 |
| 29 | 5.6 | ..... | 7.5 | 4.3 | 4.0 | 3.7 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.8 |
| 30 | 5.4 | ..... | 5.8 | a4.3 | 4.0 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | a3.6 | 3.8 |
| 31 | 5.8 | ..... | 5.5 | ..... | 4.0 | ..... | 3.6 | 3. | ..... | 3.6 | ..... | 3.7 |

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*Station rating table for Puta Creek near Guenoc, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.50 | 4 | 5.00 | 310 | 6.50 | 1,360 | 9.00 | 5,000 |
| 3.60 | 10 | 5.10 | 350 | 6.60 | 1,450 | 9.20 | 5,400 |
| 3.70 | 18 | 5.20 | 395 | 6.70 | 1,545 | 9.40 | 5,800 |
| 3.80 | 28 | 5.30 | 445 | 6.80 | 1,640 | 9.60 | 6,230 |
| 3.90 | 42 | 5.40 | 500 | 6.90 | 1,740 | 9.80 | 6,690 |
| 4.00 | 58 | 5.50 | 560 | 7.00 | 1,840 | 10.00 | 7,150 |
| 4.10 | 75 | 5.60 | 625 | 7.20 | 2,060 | 10.50 | 8,300 |
| 4.20 | 93 | 5.70 | 695 | 7.40 | 2,290 | 11.00 | 9,450 |
| 4.30 | 112 | 5.80 | 770 | 7.60 | 2,540 | 11.50 | 10,600 |
| 4.40 | 133 | 5.90 | 850 | 7.80 | 2,820 | 12.00 | 11,800 |
| 4.50 | 156 | 6.00 | 930 | 8.00 | 3,130 | 12.50 | 13,000 |
| 4.60 | 181 | 6.10 | 1,010 | 8.20 | 3,460 | 13.00 | 14,200 |
| 4.70 | 208 | 6.20 | 1,095 | 8.40 | 3,810 | 14.00 | 16,700 |
| 4.80 | 238 | 6.30 | 1,180 | 8.60 | 4,200 | | |
| 4.90 | 272 | 6.40 | 1,270 | 8.80 | 4,600 | | |

NOTE.—The above table is based on 17 discharge measurements made during 1904–5. It is well defined between gage heights 3.5 feet and 7 feet. Above 7 feet the table depends on 2 measurements at 12 feet and 13.7 feet. Above 9 feet the table is the same as for 1904.

*Estimated monthly discharge of Puta Creek near Guenoc, Cal., for 1905.*

[Drainage area, 91 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 15,450 | 133 | 1,344 | 82,640 | 14.77 | 17.03 |
| February | 1,840 | 181 | 619 | 34,380 | 6.80 | 7.08 |
| March | 1,690 | 93 | 630 | 38,740 | 6.92 | 7.98 |
| April | 395 | 112 | 288 | 17,140 | 3.16 | 3.53 |
| May | 395 | 58 | 120 | 7,379 | 1.32 | 1.52 |
| June | 625 | 10 | 85.0 | 5,058 | .934 | 1.04 |
| July | 18 | 4 | 12.4 | 762 | .136 | .157 |
| August | 10 | 4 | 8.8 | 541 | .097 | .112 |
| September | 10 | 10 | 10.0 | 595 | .110 | .123 |
| October | 18 | 10 | 15.2 | 935 | .167 | .192 |
| November | 10 | 10 | 10.0 | 595 | .110 | .123 |
| December | 75 | 10 | 22.1 | 1,359 | .243 | .280 |
| The year | 15,450 | 4 | 264 | 190,100 | 2.90 | 39.17 |

### PUTA CREEK AT WINTERS, CAL.

This station was established September 26, 1905, by R. S. Hawley. It is located about 450 feet below the Southern Pacific Railroad bridge and about 800 feet southeast of the depot at Winters, Cal.

The channel is straight for about 500 feet above and 700 feet below the cable section. The bed of the stream is composed of coarse gravel and is liable to some change at very high stages, but at ordinary stages it is not subject to much change. The current is sluggish at low water, but is swift during flood stages. There is a growth of willows and cottonwoods with wild grapevines along the banks, but the main portion of the channel is clear.

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At very high flood stages the water spreads out over the left bank for about 150 feet, reaching nearly to the foot of the left cable support. At ordinary stages, however, the water remains within the high banks.

Measurements are made during low water by wading at a point about 400 feet above the bridge, but for higher stages a cable and car are used. The cable has a span of 280 feet. For float measurements, a course 250 feet long has been marked off by setting posts painted white, 250 feet above and parallel with the cable. Floats can be dropped from the railroad bridge above and timed from these posts to the cable. The initial point of soundings is a bolt in the trunk of the oak tree to which the cable is fastened on the right bank.

The gage consists of a series of timbers painted white and located under the cable. The first or low-water section is on the right bank, and is nailed vertically to the trunk of a cottonwood tree. It has a range of about 6 feet. The second section is on the left bank and is nailed vertically to the stump of a cottonwood tree. The third section is an inclined rod anchored on the left bank with posts. The fourth section is on an eucalyptus tree on top of left bank. During 1905 the gage was read once each day by Roy Wyatt. Bench marks were established as follows: (1) A standard United States Geological Survey bench mark, located 150 feet south of the depot. Its elevation as marked on the copper plate is 131 feet, 39.23 feet above the datum of the gage. (2) A square-headed bolt in concrete, 3 feet south of the left cable support; elevation, 37.27 feet above the datum of the gage.

*Discharge measurements of Puta Creek at Winters, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| September 12 | W. B. Clapp | 16 | 8.0 | 1.09 | ..... | 8.7 |
| September 26 | Hawley and Lee | 16 | 8.8 | .97 | 4.39 | 8.5 |
| November 15 | R. S. Hawley | 16 | 8.8 | 1.33 | 4.42 | 11.7 |

*Daily gage height, in feet, of Puta Creek at Winters, Cal., for 1905.*

| Day. | Sept. | Oct. | Nov. | Dec. | Day. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 4.4 | 4.4 | 4.6 | 17 | ..... | 4.4 | 4.45 | 4.55 |
| 2 | ..... | 4.4 | 4.4 | 4.65 | 18 | ..... | 4.4 | 4.45 | 4.6 |
| 3 | ..... | 4.4 | 4.4 | 4.6 | 19 | ..... | 4.4 | 4.45 | 4.6 |
| 4 | ..... | 4.4 | 4.4 | 4.6 | 20 | ..... | 4.4 | 4.45 | 4.6 |
| 5 | ..... | 4.4 | 4.4 | 4.6 | 21 | ..... | 4.4 | 4.45 | 4.6 |
| 6 | ..... | 4.4 | 4.4 | 4.6 | 22 | ..... | 4.4 | 4.45 | 4.6 |
| 7 | ..... | 4.4 | 4.4 | 4.55 | 23 | ..... | 4.4 | 4.5 | 4.6 |
| 8 | ..... | 4.4 | 4.4 | 4.55 | 24 | ..... | 4.4 | 4.5 | 4.6 |
| 9 | ..... | 4.4 | 4.4 | 4.55 | 25 | ..... | 4.4 | 4.5 | 4.6 |
| 10 | ..... | 4.4 | 4.4 | 4.5 | 26 | 4.4 | 4.4 | 4.5 | 4.6 |
| 11 | ..... | 4.4 | 4.4 | 4.5 | 27 | 4.4 | 4.4 | 4.5 | 4.6 |
| 12 | ..... | 4.4 | 4.45 | 4.5 | 28 | 4.4 | 4.4 | 4.5 | 4.6 |
| 13 | ..... | 4.4 | 4.45 | 4.55 | 29 | 4.45 | 4.4 | 4.6 | 4.6 |
| 14 | ..... | 4.4 | 4.45 | 4.55 | 30 | 4.4 | 4.4 | 4.6 | 4.6 |
| 15 | ..... | 4.4 | 4.45 | 4.55 | 31 | ..... | 4.4 | ..... | 4.6 |
| 16 | ..... | 4.4 | 4.45 | 4.55 | | | | | |

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## SAN JOAQUIN RIVER.

### DESCRIPTION OF RIVER.

San Joaquin River is divided into two distinct parts. The valley portion forms the central drainage line of San Joaquin Valley, and during the spring is navigable for 100 miles or more. Stanislaus, Tuolumne, Merced, and Kings rivers are the largest streams in this portion of the drainage basin. The waters of Kings, Kaweah, Tule, and Kern rivers, which are located in the portion of San Joaquin Valley lying to the south and east of Fresno, although forming a portion of the drainage of San Joaquin River, seldom reach this stream. Their entire flow, except in extreme flood, is diverted and used for irrigation at points where they emerge from the foothills. The valley is fertile and almost destitute of timber. The mountainous portion of the stream drains the western slope of the Sierra Nevada between the Merced River on the north and Kings River on the south, the crest of its divide reaching an elevation of 13,000 feet in Mount Lyell and an elevation of 14,000 feet in Mount Goddard. There are numerous tributaries in this portion of the drainage basin, many of which have their source in the high elevations. The formation is of granite, which in the upper reaches is bare and sharply marked by glacial action. The middle reaches of the basin are well timbered, the timber diminishing on the lower foothills, which have a covering of brush and grass. The precipitation takes the form of snow on the higher elevations. The fall of the river is rapid, with many favorable locations for power development. There are numerous lakes in the upper reaches of the basin. A storage reservoir has been constructed on North Fork, which will tend to further regulate the flow of the river.

### SAN JOAQUIN RIVER AT HERNDON, CAL.

The gage rod at this station was established by the engineering department of the Southern Pacific Railroad Company in 1879. The old trestle bridge was torn down by the railroad company during 1899 and a new iron structure was erected in its place. A new gage rod, set to the datum of the old gage, was bolted to the western side of the central concrete pier. The bench mark is a nail in a post at the south end of the bridge on the west side, 0.2 foot above the ground, and marked "B. M." It is at an elevation of 24.12 feet above gage datum.

The channel for some distance above and below the bridge is straight, and the water has a uniform velocity. The right bank is high, rocky, and steep. The bed of the stream is composed of small gravel and shifting sand. Because of the continual changes in the cross section, which were increased by a side channel breaking through the gravel pits on the left bank of the river just above the gaging station, meter measurements were discontinued at this station at the end of 1901.

The river stage record for 1905 has been furnished by William Hood, chief engineer of the Southern Pacific Railroad Company. G. G. Nelson was the observer.

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Information in regard to this station is contained in Water-Supply Papers Nos. 81, 85, 100, and 134 of the United States Geological Survey.

*Daily gage height, in feet, of San Joaquin River at Herndon, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.5 | 3.0 | 3.9 | 4.5 | 7.0 | 6.75 | 6.1 | 3.5 | 3.15 | 2.5 | 2.4 | 2.6 |
| 2 | 3.5 | 3.15 | 4.1 | 4.5 | 6.75 | 6.6 | 6.0 | 3.5 | 3.1 | 2.5 | 2.4 | 2.65 |
| 3 | 3.3 | 4.6 | 4.25 | 4.5 | 6.6 | 6.6 | 5.75 | 3.5 | 3.0 | 2.5 | 2.4 | 2.65 |
| 4 | 3.25 | 4.4 | 4.25 | 4.5 | 6.0 | 6.75 | 6.0 | 3.5 | 3.0 | 2.5 | 2.4 | 2.6 |
| 5 | 3.15 | 4.3 | 4.25 | 5.0 | 5.5 | 6.75 | 6.0 | 3.5 | 2.9 | 2.5 | 2.4 | 2.6 |
| 6 | 3.15 | 4.75 | 4.15 | 5.25 | 5.5 | 6.4 | 5.75 | 3.5 | 2.75 | 2.5 | 2.4 | 2.6 |
| 7 | 3.15 | 4.5 | 4.15 | 5.3 | 5.65 | 6.3 | 5.5 | 3.4 | 2.75 | 2.5 | 2.4 | 2.6 |
| 8 | 3.15 | 4.0 | 4.25 | 5.5 | 5.65 | 7.15 | 5.3 | 3.4 | 2.75 | 2.5 | 2.4 | 2.6 |
| 9 | 3.1 | 3.75 | 4.3 | 6.65 | 6.0 | 7.4 | 5.3 | 3.4 | 2.75 | 2.5 | 2.4 | 2.5 |
| 10 | 3.1 | 3.5 | 4.3 | 5.75 | 5.5 | 7.4 | 5.2 | 3.4 | 2.75 | 2.5 | 2.4 | 2.5 |
| 11 | 3.1 | 3.5 | 4.5 | 5.5 | 5.5 | 7.5 | 5.15 | 3.4 | 2.75 | 2.5 | 2.4 | 2.5 |
| 12 | 3.1 | 3.5 | 4.5 | 5.5 | 5.5 | 8.3 | 5.1 | 3.3 | 2.75 | 2.5 | 2.4 | 2.5 |
| 13 | 3.1 | 3.4 | 4.5 | 5.3 | 5.5 | 8.75 | 5.0 | 3.3 | 2.75 | 2.5 | 2.4 | 2.5 |
| 14 | 3.1 | 3.3 | 7.15 | 4.75 | 5.5 | 8.0 | 4.75 | 3.3 | 2.65 | 2.5 | 2.4 | 2.5 |
| 15 | 3.1 | 3.3 | 5.5 | 4.7 | 6.0 | 8.0 | 4.75 | 3.3 | 2.65 | 2.5 | 2.4 | 2.5 |
| 16 | 3.3 | 3.25 | 5.0 | 5.1 | 7.0 | 7.75 | 4.65 | 3.25 | 2.65 | 2.5 | 2.4 | 2.5 |
| 17 | 3.15 | 3.15 | 5.0 | 5.25 | 8.5 | 8.0 | 4.65 | 3.25 | 2.65 | 2.5 | 2.4 | 2.5 |
| 18 | 3.1 | 3.15 | 5.0 | 5.0 | 8.75 | 8.25 | 4.65 | 3.25 | 2.65 | 2.5 | 2.4 | 2.5 |
| 19 | 3.0 | 3.15 | 5.0 | 5.0 | 9.65 | 8.75 | 4.65 | 3.25 | 2.65 | 2.5 | 2.4 | 2.5 |
| 20 | 3.0 | 3.15 | 6.5 | 5.0 | 8.25 | 8.3 | 4.5 | 3.25 | 2.65 | 2.5 | 2.4 | 2.6 |
| 21 | 3.0 | 3.15 | 5.0 | 4.75 | 8.6 | 7.75 | 4.5 | 3.25 | 2.65 | 2.5 | 2.4 | 2.75 |
| 22 | 3.0 | 3.15 | 5.0 | 5.0 | 8.25 | 8.0 | 4.5 | 3.25 | 2.65 | 2.5 | 2.4 | 2.75 |
| 23 | 3.0 | 3.15 | 5.0 | 5.0 | 8.3 | 7.5 | 4.5 | 3.15 | 2.65 | 2.5 | 2.4 | 2.75 |
| 24 | 3.0 | 3.15 | 5.0 | 5.0 | 8.1 | 7.15 | 4.3 | 3.15 | 2.6 | 2.4 | 2.4 | 2.75 |
| 25 | 3.0 | 3.15 | 5.0 | 5.0 | 8.25 | 6.5 | 4.3 | 3.15 | 2.6 | 2.4 | 2.4 | 2.75 |
| 26 | 3.0 | 3.15 | 5.0 | 5.5 | 8.5 | 6.65 | 4.3 | 3.15 | 2.6 | 2.4 | 2.4 | 2.75 |
| 27 | 3.0 | 3.15 | 5.25 | 5.5 | 8.3 | 6.5 | 4.25 | 3.15 | 2.6 | 2.4 | 2.4 | 2.75 |
| 28 | 3.0 | 3.15 | 5.0 | 6.0 | 7.65 | 6.5 | 4.0 | 3.15 | 2.6 | 2.4 | 2.4 | 2.75 |
| 29 | 3.0 | ..... | 5.0 | 6.0 | 7.65 | 6.5 | 3.75 | 3.15 | 2.6 | 2.4 | 2.4 | 2.75 |
| 30 | 3.0 | ..... | 4.75 | 6.15 | 6.6 | 6.6 | 3.6 | 3.15 | 2.6 | 2.4 | 2.4 | 2.75 |
| 31 | 3.0 | ..... | 4.7 | ..... | 6.75 | ..... | 3.6 | 3.15 | ..... | 2.4 | 2.6 | 2.65 |

NOTE.—Gage heights reduced to feet and tenths from feet and inches as furnished by Southern Pacific Railroad Company.

## MISCELLANEOUS MEASUREMENTS IN SAN JOAQUIN RIVER DRAINAGE BASIN.

*Pitman Creek.*—This stream is tributary to the San Joaquin River through Big Creek. An estimate was made of the discharge below the mouth of Tamarack Creek on September 2, 1905, by R. S. Hawley.

Discharge, 1.5 second-feet.

*Home Camp Creek.*—This stream is tributary to the San Joaquin River through Big Creek, which it enters at Home Camp meadow. A measurement was made on this creek on September 2, 1905, 100 feet above its mouth, by R. S. Hawley.

Width, 3.0 feet; area, 0.8 square foot; mean velocity, 1.12 feet per second; discharge, 0.90 second-foot.

*Big Creek.*—This stream is tributary to San Joaquin River from the east. A measurement was made 100 feet above the mouth of Home Camp Creek on September 2, 1905, by R. S. Hawley.



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Width, 4.5 feet; area, 1.9 square feet; mean velocity, 2.53 feet per second; discharge, 4.8 second-feet.

Discharge below the mouth of Home Camp Creek was 5.7 second-feet.

*Small Creek.*—This is a small creek which enters the South Fork of the San Joaquin from the south at Mono crossing. A measurement was made at the Mono trail crossing about 1,000 feet above its mouth on September 4, 1905, by R. S. Hawley.

Width, 2.8 feet; area, 1.1 square feet; mean velocity, 1.18 feet per second; discharge, 1.3 second-feet.

*South Fork of San Joaquin River.*—This is the principal tributary of the San Joaquin River from the south. A measurement was made September 4, 1905, at the Mono crossing by R. S. Hawley.

Width, 60 feet; area, 94 square feet; mean velocity, 1.11 feet per second; discharge, 104 second-feet.

*Mono Creek.*—This stream is tributary to South Fork of San Joaquin River from the east. A measurement was made at the Mono Trail crossing, about 2 miles above its mouth, on September 4, 1905, by R. S. Hawley.

Width, 44.5 feet; area, 37 square feet; mean velocity, 1.17 feet per second; discharge, 43 second-feet.

*Fish Creek.*—This stream is the principal tributary of the Middle Fork of the San Joaquin from the south about 10 miles above the junction of the Middle and South forks. A measurement was made on September 6, 1905, at the trail crossing, about 3 miles above its mouth, by R. S. Hawley.

Width, 29 feet; area, 36 square feet; mean velocity, 1.42 feet per second; discharge, 51 second-feet.

*Middle Fork of San Joaquin River.*—This stream drains the northeastern portion of the San Joaquin watershed. A measurement was made on September 6, 1905, at the Devils Post Pile at the trail crossing by R. S. Hawley.

Width, 42 feet; area, 41 square feet; mean velocity, 0.90 foot per second; discharge, 37 second-feet.

*Reds Creek.*—This stream enters Middle Fork of San Joaquin River one-half mile below the Devils Post Pile. A measurement was made September 6, 1905, at the Mammoth trail crossing, one-fourth mile above its mouth, by R. S. Hawley.

Width, 9 feet; area, 4.2 square feet; mean velocity, 0.93 foot per second; discharge, 3.9 second-feet.

*King Creek.*—This stream enters Middle Fork of San Joaquin River near Rainbow Falls. An estimate was made of the discharge one mile above its mouth, at Mammoth trail crossing, on September 7, 1905, by R. S. Hawley.

Discharge, 3.5 second-feet.

*Mugler Creek.*—This stream enters the San Joaquin River from the north. On September 7, 1905, an estimate of the discharge was made at the trail crossing, one-half mile below Mugler Meadow, by R. S. Hawley.

Discharge, 3.0 second-feet.

*Stevenson Creek.*—This stream enters the San Joaquin River 4 miles northwest of Shaver post-office. A measurement was made one-fourth mile above the head of Shaver Lake on September 2, 1905, by R. S. Hawley.

Width, 8 feet; area, 3.2 square feet; mean velocity, 1.22 feet per second; discharge, 3.9 second-feet.

*North Fork of the San Joaquin River.*—This stream enters the San Joaquin River 4 miles below the junction of the Middle and South forks. A measurement was made on September 7, 1905, 150 feet below the bridge, at the trail crossing, 3 miles above its mouth.

Width, 31 feet; area, 27 square feet; mean velocity, 1.33 feet per second; discharge, 36 second-feet.

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*North Fork of Willow Creek.*—This stream enters the San Joaquin from the north. A measurement was made on September 9, 1905, at "The Pines," 1½ miles above reservoir dam, by R. S. Hawley.

Width, 7 feet; area, 3.6 square feet; mean velocity, 1.19 feet per second; discharge, 4.3 second-feet.

*San Joaquin River at the San Joaquin power house.*—A measurement was made on this stream on September 9, 1905, one-half mile below the power house, by R. S. Hawley. This measurement includes practically the total flow from the whole drainage area of the San Joaquin River about this point.

Width, 148.5 feet; area, 226 square feet; mean velocity, 1.37 feet per second; discharge, 310 second-feet.

## KERN RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Kern River drains 2,345 square miles of the western slope of the Sierra Nevada at its extreme southern limits. This drainage basin is the largest of any stream discharging into the San Joaquin Valley, it having an area 600 square miles greater than that of the Kings River. It has its source in the highest elevations of the Sierra Nevada, draining the western and southern slopes of Mount Whitney and numerous other high granite peaks grouped about it, which reach elevations of over 14,000 feet. Its general direction is south for about 65 miles when it turns and flows in a southwesterly direction, discharging into the San Joaquin Valley east of Bakersfield, Cal. Extending, as it does in its upper reaches, for some distance parallel with the Sierra Nevada, it receives waters not only from the main crest on the east, but also from a somewhat lower divide on the west behind the basins of the Kaweah and Tule rivers. It has numerous tributaries, the principal ones entering from the east, which drain the higher elevations of the main crest of the Sierra Nevada. The topography is extremely rough and broken in the upper reaches of this basin, becoming less rugged in the middle portion in the vicinity of Kernville, where there is quite an extensive valley with considerable cultivated land; below this point the stream enters a rough canyon, finally discharging into the flat country of the San Joaquin Valley. The entire flow, except during extreme flood stages, is diverted and used for irrigation at points where streams emerge from the foothills.

The formation is of granite, which, above the 10,000-foot contour, is practically bare of timber growth. Between elevations of 3,000 and 10,000 feet there is a good depth of soil, with timber and brush covering; the lower reaches have a light covering of brush and grass.

There are several lakes and marshes scattered throughout this basin, but they are less numerous than in the basins farther to the north. Several power plants are located on this stream, none of which, however, receive water from storage reservoirs, the diversions being made from the natural flow of the river and again returned to the river channel. The precipitation is very light throughout this basin, with the possible exception of the high elevations surrounding Mount Whitney, where the snow remains through the summer months.

### KERN RIVER NEAR BAKERSFIELD, CAL.

This station, established in 1893 by Walter James, chief engineer of the Kern County Land Company, is located at what is known as "first point of measurement," 5 miles above Bakersfield and at the mouth of the canyon of the river.

Regular meter measurements are taken, and an automatic gage records daily fluctuations of the river heights. A. K. Warren, the engineer in charge of this work for the Kern County Land Company, attends to the discharge measurements with accuracy and precision and furnishes the Geological Survey with the final results.

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Information in regard to this station is contained in Water-Supply Papers Nos. 81, 85, 100, and 134 of the United States Geological Survey.

*Daily discharge, in second-feet, of Kern River near Bakersfield, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 280 | 305 | 435 | 799 | 1,700 | 1,953 | 1,520 | 427 | 233 | 205 | 230 | 262 |
| 2 | 285 | 326 | 458 | 848 | 1,713 | 1,979 | 1,422 | 413 | 229 | 226 | 227 | 261 |
| 3 | 272 | 435 | 480 | 934 | 1,743 | 1,932 | 1,313 | 403 | 224 | 227 | 221 | 276 |
| 4 | 278 | 486 | 500 | 997 | 1,633 | 1,931 | 1,226 | 394 | 213 | 208 | 218 | 285 |
| 5 | 290 | 517 | 512 | 1,047 | 1,542 | 1,919 | 1,215 | 376 | 216 | 196 | 215 | 277 |
| 6 | 281 | 503 | 530 | 1,070 | 1,517 | 1,879 | 1,218 | 362 | 215 | 190 | 216 | 271 |
| 7 | 269 | 452 | 545 | 1,103 | 1,453 | 1,997 | 1,171 | 345 | 217 | 181 | 231 | 267 |
| 8 | 272 | 391 | 593 | 1,138 | 1,531 | 2,154 | 1,157 | 356 | 220 | 175 | 217 | 275 |
| 9 | 270 | 364 | 616 | 1,185 | 1,461 | 2,150 | 1,115 | 358 | 218 | 176 | 225 | 278 |
| 10 | 276 | 365 | 609 | 1,119 | 1,418 | 2,066 | 1,130 | 351 | 207 | 186 | 227 | 284 |
| 11 | 280 | 351 | 613 | 1,186 | 1,367 | 2,200 | 1,125 | 349 | 202 | 192 | 230 | 264 |
| 12 | 272 | 338 | 631 | 1,180 | 1,300 | 2,567 | 1,092 | 349 | 208 | 199 | 232 | 278 |
| 13 | 266 | 334 | 785 | 1,052 | 1,298 | 2,923 | 1,038 | 352 | 218 | 206 | 233 | 265 |
| 14 | 246 | 317 | 1,154 | 971 | 1,317 | 2,978 | 958 | 352 | 225 | 206 | 228 | 241 |
| 15 | 255 | 317 | 974 | 952 | 1,425 | 3,039 | 886 | 345 | 221 | 202 | 223 | 244 |
| 16 | 255 | 361 | 996 | 991 | 1,649 | 2,933 | 799 | 338 | 218 | 199 | 234 | 240 |
| 17 | 260 | 308 | 1,143 | 995 | 1,949 | 2,948 | 748 | 327 | 215 | 203 | 240 | 238 |
| 18 | 269 | 434 | 1,140 | 1,052 | 2,312 | 2,747 | 717 | 319 | 215 | 194 | 257 | 246 |
| 19 | 277 | 417 | 1,009 | 1,121 | 2,359 | 2,569 | 665 | 318 | 208 | 198 | 263 | 259 |
| 20 | 273 | 413 | 1,309 | 1,058 | 2,528 | 2,555 | 628 | 308 | 203 | 215 | 262 | 266 |
| 21 | 305 | 401 | 1,073 | 992 | 2,549 | 2,547 | 634 | 286 | 197 | 218 | 247 | 285 |
| 22 | 329 | 386 | 957 | 964 | 2,625 | 2,539 | 597 | 279 | 194 | 217 | 243 | 272 |
| 23 | 343 | 390 | 888 | 920 | 2,558 | 2,408 | 578 | 267 | 195 | 221 | 239 | 255 |
| 24 | 311 | 397 | 871 | 895 | 2,412 | 2,154 | 558 | 269 | 196 | 230 | 227 | 233 |
| 25 | 301 | 410 | 900 | 936 | 2,456 | 1,835 | 557 | 286 | 201 | 226 | 237 | 221 |
| 26 | 298 | 420 | 929 | 1,033 | 2,560 | 1,690 | 548 | 285 | 204 | 218 | 239 | 239 |
| 27 | 281 | 432 | 999 | 1,070 | 2,598 | 1,685 | 536 | 282 | 214 | 217 | 253 | 265 |
| 28 | 276 | 434 | 978 | 1,067 | 2,378 | 1,617 | 532 | 271 | 200 | 221 | 259 | 262 |
| 29 | 271 | ..... | 919 | 1,157 | 2,120 | 1,584 | 520 | 270 | 205 | 222 | 263 | 271 |
| 30 | 276 | ..... | 1,051 | 1,451 | 1,962 | 1,563 | 488 | 265 | 205 | 224 | 245 | 255 |
| 31 | 284 | ..... | 913 | ..... | 1,930 | ..... | 451 | 250 | ..... | 226 | ..... | 257 |

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*Estimated monthly discharge of Kern River near Bakersfield, Cal., for 1905.*

[Drainage area, 2,345 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 343 | 246 | 281 | 17,280 | 0.120 | 0.138 |
| February | 517 | 305 | 396 | 21,990 | .169 | .176 |
| March | 1,300 | 435 | 823 | 50,600 | .351 | .405 |
| April | 1,451 | 799 | 1,043 | 62,060 | .445 | .496 |
| May | 2,625 | 1,298 | 1,915 | 117,800 | .817 | .942 |
| June | 3,039 | 1,563 | 2,235 | 133,000 | .953 | 1.06 |
| July | 1,520 | 451 | 876 | 53,860 | .374 | .431 |
| August | 427 | 250 | 327 | 20,110 | .139 | .160 |
| September | 233 | 194 | 211 | 12,560 | .090 | .100 |
| October | 230 | 175 | 207 | 12,730 | .088 | .101 |
| November | 263 | 215 | 236 | 14,040 | .101 | .113 |
| December | 285 | 221 | 261 | 16,050 | .111 | .128 |
| The year | 3,039 | 175 | 734 | 532,100 | .313 | 4.25 |

## TULE RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Tule River rises in the Sierra Nevada, and drains the country between the Kaweah River on the north and the Kern River on the south and east. Its drainage area is much less than that of the Kaweah River, although of the same general character. It has numerous small tributaries, few of which have their source at elevations above 8,000 feet. Its drainage basin does not extend back to the main divide, being cut off by the Kern River, which reaches to the north and drains the higher portion of Sierra Nevada to the east of Tule River. There is good timber and brush covering on the higher and middle elevations, with grass and scattering timber on the lower elevations, where the soil is extensively cultivated. Below the gaging station the water is diverted by several canals and used for the irrigation of land in the vicinity of Portersville, which is especially adapted for the raising of citrus fruits, such as oranges and lemons. During the flood period the water discharges through an old channel, and either sinks in the sand or finds its way to the old bed of Tulare Lake.

The mean precipitation in this watershed is probably not more than 20 inches, and falls principally in the form of rain.

### TULE RIVER NEAR PORTERSVILLE, CAL.

This station was established April 8, 1901. It is located about 8 miles east of Portersville near the McFarland ranch, 100 feet below wagon bridge and about 1 mile above the mouth of the South Fork of Tule River.

The channel is straight for 200 feet above and below the cable section. The right bank is high and not subject to overflow. The left bank is subject to overflow at flood stages. The bed of the stream is composed of gravel, with some large rocks, but is not subject to much change.

Discharge measurements during medium and high water are made from a car and cable; at low water measurements are made by wading.

The gage is a staff in two sections on the right bank under the cable The lower section is inclined and fastened to posts set in the ground. The higher section is vertical and nailed to the tree through which the cable passes. During 1905 the gage was read by Adah

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McFarland. Bench marks were established as follows: (1) A cross on the top of a bowlder on the right bank of the river between the cable and the bridge; elevation, 13.10 feet. (2) A point marked with white paint on a dark granite bowlder 55 feet south of the rock pier of the bridge; elevation, 10.05 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 85, 100, and 134 of the United States Geological Survey.

*Discharge measurements of Tule River near Portersville, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 22 | F. R. S. Buttemer | 71 | 107 | 2.05 | 2.50 | 219 |
| May 19 | R. S. Hawley | 77 | 152 | 2.34 | 3.00 | 355 |
| June 13 | do | 69 | 97 | 1.68 | 2.27 | 163 |
| July 26 | do | 33 | 26 | .96 | 1.16 | 25 |
| September 18 | C. H. Lee | 26 | 17 | .58 | .92 | 10 |
| September 26 | Clapp and Holley | 24 | 16 | .50 | .91 | 8.0 |
| October 25 | Hawley and Lee | 30 | 22 | .70 | 1.10 | 15.5 |

*Daily gage height, in feet, of Tule River near Portersville, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.7 | 1.45 | 1.7 | 2.3 | 2.5 | 2.55 | 1.7 | 1.05 | 0.9 | 1.1 | 1.05 | 1.9 |
| 2 | 1.7 | 2.30 | 1.7 | 2.4 | 3.0 | 2.55 | 1.7 | 1.05 | .9 | 1.05 | 1.1 | 1.85 |
| 3 | 1.65 | 2.0 | 1.75 | 2.5 | 2.9 | 2.5 | 1.65 | 1.05 | .9 | 1.05 | 1.1 | 1.85 |
| 4 | 1.6 | 2.0 | 1.75 | 2.6 | 2.8 | 2.45 | 1.6 | 1.05 | .9 | 1.0 | 1.1 | 1.8 |
| 5 | 1.6 | 1.9 | 1.75 | 2.55 | 2.5 | 2.45 | 1.55 | 1.05 | .9 | 1.0 | 1.1 | 1.8 |
| 6 | 1.6 | 1.8 | 1.8 | 2.55 | 2.5 | 2.45 | 1.5 | 1.0 | .9 | 1.0 | 1.1 | 1.8 |
| 7 | 1.55 | 1.75 | 1.8 | 2.55 | 3.05 | 2.4 | 1.45 | 1.0 | .9 | 1.0 | 1.1 | 1.8 |
| 8 | 1.55 | 1.7 | 1.8 | 2.5 | 3.2 | 2.35 | 1.4 | 1.0 | .9 | 1.0 | 1.15 | 1.8 |
| 9 | 1.5 | 1.65 | 1.75 | 2.5 | 2.95 | 2.35 | 1.4 | 1.0 | .9 | 1.05 | 1.15 | 1.8 |
| 10 | 1.5 | 1.6 | 1.75 | 2.4 | 2.85 | 2.3 | 1.4 | 1.0 | .95 | 1.05 | 1.15 | 1.8 |
| 11 | 1.5 | 1.6 | 1.7 | 2.35 | 2.8 | 2.3 | 1.4 | 1.0 | .95 | 1.0 | 1.15 | 1.8 |
| 12 | 1.45 | 1.6 | 1.75 | 2.3 | 2.75 | 2.4 | 1.35 | .95 | .95 | 1.0 | 1.15 | 1.8 |
| 13 | 1.45 | 1.6 | 3.1 | 2.35 | 2.7 | 2.35 | 1.35 | .95 | .95 | .95 | 1.15 | 1.8 |
| 14 | 1.4 | 1.6 | 2.8 | 2.35 | 2.9 | 2.3 | 1.3 | .95 | 1.0 | 1.0 | 1.15 | 1.8 |
| 15 | 1.4 | 1.7 | 2.6 | 2.4 | 3.0 | 2.25 | 1.3 | .95 | .95 | 1.0 | 1.2 | 1.8 |
| 16 | 1.4 | 1.75 | 3.0 | 2.35 | 3.2 | 2.25 | 1.3 | .95 | .95 | 1.0 | 1.2 | 1.8 |
| 17 | 1.4 | 1.75 | 3.0 | 2.3 | 3.3 | 2.1 | 1.25 | .95 | .95 | 1.0 | 1.3 | 1.8 |
| 18 | 1.4 | 1.8 | 2.9 | 2.3 | 3.1 | 2.0 | 1.25 | .95 | .95 | 1.0 | 1.3 | 1.9 |
| 19 | 1.4 | 1.8 | 4.1 | 2.5 | 3.0 | 1.95 | 1.2 | .95 | .95 | 1.0 | 1.3 | 1.9 |
| 20 | 1.4 | 1.75 | 3.7 | 2.45 | 3.0 | 1.9 | 1.2 | .95 | .95 | 1.0 | 1.7 | 1.9 |
| 21 | 1.6 | 1.75 | 3.5 | 2.45 | 2.95 | 1.85 | 1.2 | .95 | .95 | 1.0 | 1.7 | 1.9 |
| 22 | 1.6 | 1.75 | 3.1 | 2.4 | 2.8 | 1.8 | 1.15 | .95 | .95 | 1.0 | 1.65 | 1.9 |
| 23 | 1.5 | 1.7 | 2.8 | 2.4 | 2.7 | 1.8 | 1.15 | .95 | .95 | 1.0 | 1.65 | 1.9 |
| 24 | 1.5 | 1.7 | 2.5 | 2.35 | 2.75 | 1.8 | 1.1 | .95 | .95 | 1.0 | 1.65 | 1.85 |
| 25 | 1.5 | 1.7 | 2.3 | 2.4 | 2.8 | 1.9 | 1.1 | .95 | .95 | 1.0 | 1.6 | 1.85 |
| 26 | 1.5 | 1.7 | 2.3 | 2.4 | 2.8 | 1.85 | 1.15 | .95 | .95 | 1.0 | 1.6 | 1.9 |
| 27 | 1.5 | 1.7 | 2.3 | 2.45 | 2.8 | 1.85 | 1.1 | .95 | .95 | 1.0 | 2.1 | 2.0 |
| 28 | 1.5 | 1.7 | 2.25 | 2.5 | 2.75 | 1.8 | 1.1 | .9 | 1.0 | 1.0 | 1.95 | 2.0 |
| 29 | 1.5 | ..... | 2.9 | 2.6 | 2.7 | 1.8 | 1.15 | .9 | 1.0 | 1.0 | 1.85 | 2.1 |
| 30 | 1.45 | ..... | 2.4 | 2.7 | 2.65 | 1.75 | 1.05 | .9 | 1.0 | 1.05 | 1.9 | 2.1 |
| 31 | 1.4 | ..... | 2.3 | ..... | 2.6 | ..... | 1.05 | .9 | ..... | 1.05 | ..... | 2.1 |

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*Station rating table for Tule River near Portersville, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.90 | 7 | 1.80 | 82 | 2.70 | 270 | 3.60 | 581 |
| 1.00 | 12 | 1.90 | 98 | 2.80 | 297 | 3.70 | 626 |
| 1.10 | 18 | 2.00 | 115 | 2.90 | 325 | 3.80 | 672 |
| 1.20 | 24 | 2.10 | 133 | 3.00 | 355 | 3.90 | 720 |
| 1.30 | 31 | 2.20 | 152 | 3.10 | 386 | 4.00 | 770 |
| 1.40 | 38 | 2.30 | 173 | 3.20 | 419 | 4.10 | 822 |
| 1.50 | 46 | 2.40 | 195 | 3.30 | 455 | | |
| 1.60 | 56 | 2.50 | 219 | 3.40 | 494 | | |
| 1.70 | 68 | 2.60 | 244 | 3.50 | 537 | | |

NOTE.—The above table is based on seven discharge measurements made during 1905. It is well defined between gage heights 0.9 foot and 3 feet.

*Estimated monthly discharge of Tule River near Portersville, Cal., for 1905.*

[Drainage area, 437 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 68 | 38 | 47.4 | 2,914 | 0.108 | 0.124 |
| February | 173 | 42 | 75.9 | 4,215 | .174 | .181 |
| March | 822 | 68 | 230 | 14,140 | .526 | .606 |
| April | 270 | 173 | 205 | 12,200 | .469 | .523 |
| May | 455 | 219 | 313 | 19,250 | .716 | .826 |
| June | 232 | 75 | 146 | 8,688 | .334 | .373 |
| July | 68 | 15 | 32.9 | 2,023 | .075 | .086 |
| August | 15 | 7 | 9.8 | 603 | .022 | .025 |
| September | 12 | 7 | 8.2 | 488 | .019 | .021 |
| October | 18 | 8 | 12.6 | 775 | .029 | .033 |
| November | 133 | 15 | 42.4 | 2,523 | .097 | .108 |
| December | 133 | 82 | 94.2 | 5,792 | .216 | .249 |
| The year | 822 | 7 | 101 | 73,610 | .232 | 3.16 |

## MISCELLANEOUS MEASUREMENTS IN TULE RIVER DRAINAGE BASIN.

*South Fork of Tule River near Success, Cal.*—The following measurements were made at a point one-half mile above junction of South Fork with Main Tule River.

May 19: Width, 28 feet; area, 32 feet; mean velocity, 2.86 feet per second; discharge, 90 second-feet.

September 26, stream dry.

*North Fork of Tule River near Springville, Cal.*—A measurement was made September 26 at road crossing one-half mile above junction with Middle Fork of Kings River.

Water standing in pools; discharge, 00 second-feet.

*Middle Fork of Tule River near Springville, Cal.*—This stream is the principal tributary of Kaweah River and furnishes practically all the water of this river during low-water flow. A measurement was made September 27 one-fourth mile above clubhouse and 2 miles above the town of Springville.

Width, 33.5 feet; area, 36 square feet; mean velocity, 0.64 foot per second; discharge, 23 second-feet.

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*South Fork of Middle Fork of Tule River near Springville, Cal.*—This stream is a tributary to Middle Fork of Kaweah River. A measurement was made September 27 at a point 100 feet above its junction with Middle Fork.

Width, 8.4 feet; area, 4.0 square feet; mean velocity, 2.20 feet per second; discharge, 8.8 second-feet.

*North Fork of Middle Fork of Tule River near Springville, Cal.*—This stream is tributary to Middle Fork of Kaweah River. A measurement was made September 27 100 feet above its junction with Middle Fork.

Width, 7.9 feet; area, 5.9 square feet; mean velocity, 2.19 feet per second; discharge, 12.9 second-feet.

## KAWEAH RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Kaweah River drains the western slope of the Sierra Nevada between the basins of Kings River on the north and Kern and Tule rivers on the south. This is an important stream, but its watershed is only about one-third that of Kings River and is much less elevated and snow covered than those of the Kings and Kern rivers. It has a number of tributaries which have their source in numerous lakes and meadows on the higher elevations. The formation is of granite and similar in every way to that in the Kings River basin. The greater part of the area of 619 square miles above the gaging station is well covered with brush and timber. In this basin is situated the Sequoia National Park, where the largest grove of big trees (*Sequoia gigantea*) of the Sierra Nevada is found. This grove is known as the "Giant Forest," and is one of the many points of interest of the Sierra Nevadas. There are two power plants on this stream owned by the Mount Whitney Power Company, which divert water from the Middle and East forks. This company has constructed several small storage reservoirs on the upper reaches of this basin. This has been done by building low dams at the outlet of some of the larger lakes. The stored water is held back for use during the low-water flow of the stream, and is of great benefit to the irrigators in the valley during the late summer months. About 6 miles below the gaging station the river leaves the foothills and flows across San Joaquin Valley in a general southwesterly direction to the old bed of Tulare Lake. After it leaves the foothills many canals divert water for the purpose of irrigating land in Tulare County, which is especially adapted to the raising of fruits.

The mean annual precipitation in the basin above the gaging station is from 20 to 40 inches, which falls in the form of snow over probably one-half the area.

### KAWEAH RIVER BELOW THREE RIVERS, CAL.

This station was established April 29, 1903, by W. H. Stearns. It is located at a point three-fourths of a mile below the confluence of the North, Middle, and South forks. It is 10 miles from the Southern Pacific Railroad station at Lemon Cove, Tulare County, Cal., and one-fourth of a mile west of the wagon road from Exeter to Three Rivers.

The channel is straight for 400 feet above and below the station. The current is swift at high stages, but sluggish at low water. There are rapids about 400 feet above and 500 feet below the cable. The right bank is low and subject to overflow at high stages. The left bank is high enough to be above overflow. There are willow trees along the water's edge on both banks, and a line of willows, sycamores, and cottonwoods back from the water's edge on the left bank. The bed of the stream is composed of sand, gravel, and large bowlders. The section is probably permanent.

Discharge measurements are made from a cable and car. The initial point for soundings is a sycamore tree on the left bank of the stream, to which the cable is fastened.

The low-water gage is an inclined timber on the left bank. The high-water gage is a timber securely nailed to a willow tree on the left bank. During 1905 the gage was read by J. O. Carter. Bench marks were established as follows: (1) A point marked "B. M." with black paint on a large rock 10 feet upstream from the tree to which the cable is attached;

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elevation, 13.95 feet. (2) A point on rock marked with white paint 7 feet upstream from the 75-foot mark on the cable; elevation, 15.89 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 100 and 134 of the United States Geological Survey.

*Discharge measurements of Kaweah River below Three Rivers, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 18 | F. R. S. Buttemer | 157 | 464 | 1.24 | 5.94 | 577 |
| March 20 | do | 160 | 526 | 1.55 | 6.26 | 815 |
| May 20 | R. S. Hawley | 175 | 647 | 2.70 | 7.25 | 1,746 |
| June 14 | do | 170 | 653 | 2.27 | 7.00 | 1,480 |
| July 25 | do | 140 | 306 | 0.44 | 4.83 | 136 |
| September 17 | C. H. Lee | 29 | 44 | 0.73 | 4.25 | 32 |
| October 24 [a] | Hawley and Lee | 56 | 61 | 0.80 | 4.30 | 49 |

[a] Section 400 feet below cable.

*Daily gage height, in feet, of Kaweah River below Three Rivers, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.9 | 4.9 | 5.4 | 5.8 | 6.8 | 7.05 | 6.05 | 4.65 | 4.3 | 4.3 | 4.2 | 4.6 |
| 2 | 4.85 | 5.95 | 5.45 | 5.9 | 6.7 | 7.0 | 6.0 | 4.65 | 4.3 | 4.35 | 4.2 | 4.6 |
| 3 | 4.8 | 5.4 | 5.5 | 6.0 | 6.55 | 7.0 | 5.9 | 4.65 | 4.2 | 4.3 | 4.25 | 4.55 |
| 4 | 4.75 | 5.2 | 5.5 | 6.1 | 6.4 | 7.3 | 5.9 | 4.65 | 4.3 | 4.25 | 4.25 | 4.5 |
| 5 | 4.7 | 5.65 | 5.5 | 6.2 | 6.3 | 6.8 | 5.8 | 4.6 | 4.3 | 4.3 | 4.25 | 4.6 |
| 6 | 4.7 | 5.2 | 5.4 | 6.2 | 6.4 | 7.45 | 5.75 | 4.6 | 4.3 | 4.2 | 4.3 | 4.5 |
| 7 | 4.7 | 5.15 | 5.45 | 6.3 | 6.55 | 7.05 | 5.75 | 4.6 | 4.3 | 4.25 | 4.3 | 4.6 |
| 8 | 4.7 | 5.15 | 5.5 | 6.25 | 6.6 | 6.95 | 5.7 | 4.55 | 4.3 | 4.2 | 4.3 | 4.55 |
| 9 | 4.7 | 5.15 | 5.5 | 6.25 | 6.5 | 6.8 | 5.7 | 4.55 | 4.3 | 4.3 | 4.3 | 4.55 |
| 10 | 4.7 | 5.0 | 5.45 | 6.2 | 6.35 | 7.05 | 5.65 | 4.55 | 4.2 | 4.25 | 4.3 | 4.55 |
| 11 | 4.7 | 5.1 | 5.55 | 6.15 | 6.3 | 7.15 | 5.6 | 4.55 | 4.25 | 4.2 | 4.3 | 4.5 |
| 12 | 4.6 | 5.0 | [a] 5.6 | 6.0 | 6.3 | 7.35 | 5.5 | 4.55 | 4.25 | 4.2 | 4.25 | 4.5 |
| 13 | 4.7 | 5.1 | 6.9 | 6.0 | 6.35 | 7.25 | 5.4 | 4.55 | 4.25 | 4.2 | 4.25 | 4.5 |
| 14 | 4.6 | 5.0 | 5.9 | 6.0 | 6.55 | 7.15 | 5.3 | 4.6 | 4.25 | 4.2 | 4.3 | 4.55 |
| 15 | 4.6 | 5.0 | 5.8 | 6.1 | 6.9 | 7.15 | 5.25 | 4.6 | 4.25 | 4.2 | 4.25 | 4.55 |
| 16 | 4.65 | 5.45 | 6.1 | 6.2 | 7.3 | 7.15 | 5.2 | 4.6 | 4.25 | 4.25 | 4.3 | 4.55 |
| 17 | 4.7 | 5.35 | 6.0 | 6.2 | 7.4 | 7.1 | 5.2 | 4.45 | 4.2 | 4.25 | 4.3 | 4.5 |
| 18 | 4.65 | 5.65 | 5.95 | 6.35 | 7.35 | 7.0 | 5.1 | 4.4 | 4.25 | [a] 4.25 | 4.4 | 4.5 |
| 19 | 4.7 | 5.3 | 7.0 | 6.3 | 7.4 | 6.95 | 5.1 | 4.4 | 4.2 | 4.25 | 4.3 | 4.55 |
| 20 | 4.7 | 5.2 | 6.2 | 6.25 | 7.3 | 6.9 | 5.0 | 4.35 | 4.25 | 4.25 | 4.45 | 4.6 |
| 21 | 4.95 | 5.2 | 6.1 | 6.15 | 7.45 | 6.8 | 5.0 | 4.4 | 4.25 | 4.2 | 4.5 | 4.6 |
| 22 | 4.95 | 5.15 | 5.9 | 6.15 | 7.4 | 6.7 | 5.0 | 4.4 | 4.2 | 4.2 | 4.4 | 4.5 |
| 23 | 4.8 | 5.1 | [a] 5.9 | 6.15 | 7.3 | 6.6 | 4.95 | 4.4 | 4.2 | 4.2 | 4.4 | 4.5 |
| 24 | 4.8 | 5.15 | 5.9 | 6.2 | 7.4 | 6.4 | 4.9 | 4.4 | 4.2 | 4.25 | 4.4 | 4.5 |
| 25 | 4.75 | 5.2 | 5.9 | 6.35 | 7.5 | 6.30 | 4.9 | 4.4 | 4.2 | 4.3 | 4.4 | 4.6 |
| 26 | 4.7 | 5.2 | 6.1 | 6.3 | 7.35 | 6.35 | 4.85 | 4.4 | 4.2 | 4.25 | 4.4 | 4.5 |
| 27 | 4.7 | 5.1 | 6.0 | 6.35 | 7.1 | 6.0 | 4.85 | 4.4 | 4.2 | 4.25 | 4.55 | 4.5 |
| 28 | 4.7 | 5.4 | 5.85 | 6.5 | 6.9 | 6.2 | 4.8 | 4.35 | 4.2 | 4.2 | 4.6 | 4.6 |
| 29 | 4.7 | ..... | 6.2 | 6.75 | 6.75 | 6.15 | 4.7 | 4.3 | 4.4 | 4.2 | 4.6 | 4.6 |
| 30 | 4.7 | ..... | 5.9 | 6.85 | 6.85 | 6.15 | 4.7 | 4.3 | 4.45 | 4.25 | 4.6 | 4.6 |
| 31 | 4.7 | ..... | 5.7 | ..... | 6.95 | ..... | 4.7 | 4.25 | ..... | 4.2 | ..... | 4.65 |

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*Station rating table for Kaweah River below Three Rivers, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 4.20 | 40 | 5.10 | 210 | 6.00 | 625 | 6.90 | 1,375 |
| 4.30 | 49 | 5.20 | 240 | 6.10 | 690 | 7.00 | 1,480 |
| 4.40 | 61 | 5.30 | 274 | 6.20 | 760 | 7.10 | 1,590 |
| 4.50 | 75 | 5.40 | 312 | 6.30 | 835 | 7.20 | 1,700 |
| 4.60 | 91 | 5.50 | 350 | 6.40 | 915 | 7.30 | 1,815 |
| 4.70 | 109 | 5.60 | 395 | 6.50 | 1,000 | 7.40 | 1,935 |
| 4.80 | 130 | 5.70 | 445 | 6.60 | 1,090 | 7.50 | 2,060 |
| 4.90 | 154 | 5.80 | 500 | 6.70 | 1,180 | | |
| 5.00 | 180 | 5.90 | 560 | 6.80 | 1,275 | | |

NOTE.—The above table is based on seven discharge measurements made during 1905. It is well defined throughout.

*Estimated monthly discharge of Kaweah River below Three Rivers, Cal., for 1905.*

[Drainage area, 520 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 167 | 91 | 116 | 7,133 | 0.223 | 0.257 |
| February | 592 | 154 | 258 | 14,330 | .496 | .516 |
| March | 1,480 | 312 | 553 | 34,000 | 1.06 | 1.22 |
| April | 1,325 | 500 | 783 | 46,590 | 1.51 | 1.68 |
| May | 2,060 | 835 | 1,386 | 85,220 | 2.67 | 3.08 |
| June | 1,998 | 625 | 1,348 | 80,210 | 2.59 | 2.89 |
| July | 658 | 109 | 303 | 18,630 | .583 | .672 |
| August | 100 | 44 | 76.6 | 4,710 | .147 | .170 |
| September | 68 | 40 | 45.2 | 2,690 | .087 | .097 |
| October | 55 | 40 | 43.4 | 2,669 | .083 | .096 |
| November | 91 | 40 | 56.6 | 3,368 | .109 | .122 |
| December | 100 | 75 | 83.0 | 5,103 | .160 | .184 |
| The year | 2,060 | 40 | 421 | 304,700 | .810 | 10.98 |

## MISCELLANEOUS MEASUREMENTS IN KAWEAH RIVER DRAINAGE BASIN.

*Marble Fork in Sequoia National Park, Cal.*—This stream is one of the principal tributaries of the Kaweah River. A measurement was made October 12 by W. B. Clapp at a point 100 yards above its junction with the Middle Fork of Kaweah River.

Width, 8.1 feet; area, 6.0 square feet, mean velocity, 0.83 foot per second; discharge, 5.0 second-feet.

*Middle Fork of Kaweah River in Sequoia National Park, Cal.*—This stream is one of the principal tributaries of Kaweah River. A measurement was made October 12 by W. B. Clapp at a point 100 yards above its junction with Marble Fork.

Width, 24.5 feet; area, 32.2 square feet; mean velocity, 0.51 foot per second; discharge, 16.3 second-feet.

*South Fork of Kaweah River near Three Rivers, Cal.*—A measurement of this stream was made October 11 by W. B. Clapp, 2 miles above junction of Grouse Creek with South Fork, about 8 miles above the town of Three Rivers.

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Width, 3.5 feet; area, 1.7 square-feet; mean velocity, 2.53 feet per second; discharge, 4.3 second-feet.

*East Fork of Kaweah River at power house of Mount Whitney Power Company.*—Estimates of discharge of this stream were made by W. B. Clapp at the power house of Mount Whitney Power Company, 3 miles above the town of Three Rivers, Cal. The estimated discharge was calculated from discharge of nozzles at Mount Whitney Power Company's Plant.

September 28: Operating three Doble wheels. Wheel No. 1, 1½-inch nozzle; wheel No. 2, 2-inch nozzle; wheel No. 3, 2¼-inch nozzle; effective head 1,290 feet; coefficient used, 0.98; discharge, 17.4 second-feet.

October 13: Two wheels running. Wheel No. 2, 2-inch nozzle; wheel No. 3, 2¼-inch nozzle; wheel No. 1, not running; effective head, 1,290 feet; coefficient used, 0.98; discharge, 14 second-feet.

*Mount Whitney Power Company's flume, 100 feet below head-gate at boundary line Sequoia National Park.*—The following measurements were made during 1905 by W. B. Clapp.

September 28: Width, 6.6 feet; area, 7.9 square feet; mean velocity, 2.18 feet per second; discharge, 17.2 second-feet.

October 12: Width, 4.75 feet; area, 6.4 square feet; mean velocity, 2.95 feet per second; discharge, 18.9 second-feet.

These measurements give total flow of Middle Fork of Kaweah River, including Marble Fork.

*North Fork Kaweah River near Three Rivers, Cal.*—A measurement of this stream was made October 13 by W. B. Clapp at a point 5 miles above junction of South Fork with Middle Fork of Kaweah River.

Width, 12 feet; area, 3.2 square feet; mean velocity, 1.50 feet per second; discharge, 4.8 second-feet.

## KINGS RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Kings River rises on the western slope of the Sierra Nevada and drains the country located between the San Joaquin River on the north and the Kaweah and Kern rivers on the south. The crest of the Sierra Nevada at the head of this basin reaches elevations of over 14,000 feet, and here is the most rugged portion of the range; the sharp and precipitous peaks characteristic of this part of the Sierra Nevada produce the grandest scenery to be found in the United States. The main tributaries of this stream flow through great canyons cut in the granite, with high precipitous walls. The Kings River Canyon on the South Fork and Tehipite Valley on the Middle Fork rival the famed Yosemite Valley for grandeur of scenery. There are numerous tributaries, many of which have their sources in perpetual snow banks on the higher elevation. A large number of small lakes on the higher elevations are fed by small streams from perpetual snow banks or glaciers, and in them many of the tributaries have their source. The formation is of granite, which above an elevation of 10,000 feet is bare, with scanty vegetation, being carved by the action of glaciers; below the 10,000-foot contour is a heavy covering of timber and underbrush. Extensive groves of big trees are scattered throughout this basin. On the lower elevations along the foothills the soil covering is light with a grass growth used for pasturage. Fully 80 per cent of the drainage area is now included in the boundaries of the Sierra Forest Reserve which is patrolled for the prevention of fires and illegal herding. Below the gaging station, which is located at the point where the river leaves the foothills, canals divert the water for use in the valley lands of Fresno, Kings, and Tulare counties, where the climate and soil are especially adapted to the raising of grapes, fruits, etc., and the soil is under a high state of cultivation. During the period of flood discharge some water passes these canals and finds its way across Kings River delta in the natural channel to the old bed of Tulare Lake, which is now but an intermittent lake due largely to the diversion of water for irrigation purposes from the streams which drain into it.

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There is a drainage area of 1,742 square miles above the Red Mountain gaging station. The mean annual precipitation for this area varies from about 30 to 60 inches, which over a greater portion of the basin falls in the form of snow. The greater discharge of this stream is in the spring months when the snow is melting.

### KINGS RIVER NEAR SANGER, CAL.

This station was established September 3, 1895, by J. B. Lippincott. It is located 15 miles east of Sanger, Cal., near the mouth of the canyon, and is above all diversions.

The channel is nearly straight for 300 feet above and below the station, and has a width of 180 feet at ordinary stages. The bed of the stream is composed of gravel and small bowlders and changes but little. The right bank is high and not subject to overflow. The left bank is subject to overflow during extreme high water. The current is swift.

Discharge measurements are made by means of a cable and car. The initial point for soundings is an eyebolt embedded in concrete on the right bank of river. An automatic river stage register was installed April 18, 1903. There is also an inclined wooden gage near by from which readings were formerly taken and which is now used in checking the self-recording gage. Mr. O. G. Williams reads the gage once each day and also examines the automatic register to see that it is in proper working order. The mean daily gage height is determined from the register sheets by the use of planimeter. The bench mark is a cross marked on a rock which is 24 feet upstream from the self-recording register; elevation, 18.00 feet above the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 85, 100, and 134 of the United States Geological Survey.

*Discharge measurements of Kings River near Sanger, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 21 | F. R. S. Buttemer | 217 | 883 | 2.73 | 6.91 | 2,406 |
| May 22 | R. S. Hawley | 317 | 1,827 | 4.95 | 10.10 | 9,046 |
| June 15 | do | 314 | 1,808 | 4.67 | 10.10 | 8,446 |
| July 24 | do | 169 | 584 | 1.69 | 5.42 | 986 |
| August 19 | do | 145 | 390 | .97 | 4.33 | 382 |
| September 16 | C. H. Lee | 126 | 317 | .63 | 3.82 | 199 |
| October 21 | Hawley and Lee | 113 | 128 | 1.53 | 3.79 | 186 |

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*Mean daily gage height, in feet, of Kings River near Sanger, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.65 | 5.0 | 5.5 | 6.25 | 8.9 | 9.0 | 7.8 | 4.95 | 4.1 | 4.05 | 3.8 | 4.10 |
| 2 | 4.55 | 5.65 | 5.7 | 6.5 | 8.35 | 9.05 | 7.6 | 4.85 | 4.05 | 4.0 | 3.8 | 4.05 |
| 3 | 4.45 | 5.6 | 5.85 | 6.6 | 8.05 | 9.15 | 7.5 | 4.8 | 4.0 | 4.0 | 3.8 | 4.0 |
| 4 | 4.45 | 5.45 | 5.95 | 6.7 | 7.7 | 8.85 | 7.4 | 4.8 | 4.0 | 3.9 | 3.8 | 4.1 |
| 5 | 4.4 | 5.7 | 5.9 | 6.9 | 7.55 | 8.7 | 7.3 | 4.7 | 4.0 | 3.85 | 3.8 | 4.15 |
| 6 | 4.4 | 5.65 | 5.9 | 7.05 | 7.65 | 9.05 | 7.25 | 4.65 | 4.0 | 3.85 | 3.8 | 4.1 |
| 7 | a 4.4 | 5.4 | 5.9 | 7.2 | 7.75 | 9.35 | 7.25 | 4.6 | 4.0 | 3.8 | 3.8 | 4.1 |
| 8 | a 4.4 | 5.3 | 5.95 | 7.2 | 7.9 | 9.3 | 7.2 | 4.6 | 3.95 | 3.8 | 3.8 | 4.1 |
| 9 | 4.4 | 5.25 | 5.95 | 7.25 | 7.7 | 9.1 | 7.2 | 4.6 | 3.95 | 3.8 | 3.8 | 4.05 |
| 10 | 4.35 | 5.15 | 5.9 | 7.25 | 7.4 | 9.4 | 7.2 | 4.65 | 3.9 | 3.8 | 3.8 | 4.0 |
| 11 | 4.4 | 5.05 | 5.9 | 7.0 | 7.4 | 9.8 | 7.15 | 4.6 | 3.9 | 3.75 | a 3.8 | 4.0 |
| 12 | 4.3 | 5.0 | 5.95 | 6.75 | 7.4 | 10.25 | 7.0 | 4.55 | 3.9 | 3.75 | 3.8 | 4.0 |
| 13 | 4.2 | 4.85 | 7.15 | 6.6 | 7.45 | 10.3 | 6.7 | 4.55 | 3.9 | 3.75 | 3.8 | 4.0 |
| 14 | 4.35 | 4.85 | 7.35 | 6.6 | 7.95 | 10.2 | 6.4 | 4.5 | 3.9 | 3.7 | 3.8 | 4.0 |
| 15 | a 4.35 | 4.85 | 6.65 | 6.9 | 8.8 | 10.0 | 6.2 | 4.45 | 3.9 | 3.7 | 3.8 | 4.0 |
| 16 | 4.35 | 5.0 | 6.55 | 7.05 | 9.6 | 9.9 | 6.0 | 4.45 | 3.85 | 3.7 | 3.8 | 4.0 |
| 17 | 4.4 | 5.4 | 6.75 | 7.0 | 10.25 | 9.85 | 5.85 | 4.4 | 3.8 | 3.7 | 3.8 | 4.0 |
| 18 | 4.4 | 5.25 | 6.75 | 7.3 | 10.15 | 9.6 | 5.75 | 4.4 | 3.8 | 3.75 | 3.8 | 4.0 |
| 19 | 4.35 | 5.2 | 7.0 | 7.2 | 10.15 | 9.4 | 5.65 | 4.35 | 3.8 | 3.75 | 3.9 | 4.0 |
| 20 | 4.45 | 5.15 | 7.2 | 6.9 | 10.05 | 9.4 | 5.6 | 4.3 | 3.8 | 3.8 | 3.95 | 4.05 |
| 21 | 4.7 | 5.1 | 6.9 | 6.85 | 10.15 | 9.45 | 5.55 | 4.3 | 3.8 | 3.8 | 4.0 | 4.1 |
| 22 | 4.8 | 5.1 | 6.55 | 6.8 | 10.15 | 9.4 | 5.55 | 4.3 | 3.75 | 3.8 | 3.9 | 4.0 |
| 23 | 4.6 | 5.15 | 6.4 | 6.8 | 9.95 | 8.95 | 5.5 | 4.3 | 3.75 | 3.8 | 3.9 | 3.9 |
| 24 | 4.6 | 5.2 | 6.5 | 7.1 | 9.95 | 8.45 | 5.5 | 4.25 | 3.75 | 3.8 | 3.8 | 3.9 |
| 25 | 4.55 | 5.25 | 6.6 | 7.5 | 10.15 | 8.2 | 5.5 | 4.2 | 3.75 | 3.7 | 3.8 | a 3.9 |
| 26 | 4.5 | 5.3 | 6.8 | 7.5 | 10.15 | 8.25 | 5.5 | 4.2 | 3.7 | 3.7 | 3.85 | 3.9 |
| 27 | 4.45 | 5.3 | 6.7 | 7.75 | 9.4 | 8.05 | 5.45 | 4.2 | 3.7 | 3.7 | 3.9 | 4.0 |
| 28 | 4.45 | 5.35 | 6.4 | 8.2 | 8.85 | 7.95 | 5.4 | 4.15 | 3.7 | 3.7 | 4.1 | 4.0 |
| 29 | 4.45 | ..... | 6.55 | 8.75 | 8.5 | 8.0 | 5.25 | 4.1 | 3.75 | 3.75 | 4.0 | 4.0 |
| 30 | 4.45 | ..... | 6.4 | 9.05 | 8.65 | 8.0 | 5.15 | 4.1 | 3.95 | 3.75 | a 4.0 | 4.0 |
| 31 | 4.5 | ..... | 6.25 | ..... | 8.9 | ..... | 5.05 | 4.1 | ..... | 3.75 | ..... | 3.9 |

a Gage height estimated.

*Station rating table for Kings River near Sanger, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.70 | 150 | 5.00 | 740 | 6.30 | 1,730 | 8.00 | 3,850 |
| 3.80 | 175 | 5.10 | 805 | 6.40 | 1,820 | 8.20 | 4,190 |
| 3.90 | 205 | 5.20 | 870 | 6.50 | 1,920 | 8.40 | 4,570 |
| 4.00 | 240 | 5.30 | 940 | 6.60 | 2,020 | 8.60 | 4,980 |
| 4.10 | 280 | 5.40 | 1,010 | 6.70 | 2,120 | 8.80 | 5,425 |
| 4.20 | 325 | 5.50 | 1,085 | 6.80 | 2,230 | 9.00 | 5,900 |
| 4.30 | 370 | 5.60 | 1,160 | 6.90 | 2,340 | 9.20 | 6,380 |
| 4.40 | 420 | 5.70 | 1,235 | 7.00 | 2,460 | 9.40 | 6,915 |
| 4.50 | 470 | 5.80 | 1,310 | 7.20 | 2,705 | 9.60 | 7,495 |
| 4.60 | 520 | 5.90 | 1,390 | 7.40 | 2,965 | 9.80 | 8,115 |
| 4.70 | 570 | 6.00 | 1,470 | 7.60 | 3,240 | 10.00 | 8,770 |
| 4.80 | 625 | 6.10 | 1,550 | 7.80 | 3,535 | 10.20 | 9,450 |
| 4.90 | 680 | 6.20 | 1,640 | | | | |

NOTE.—The above table is based on discharge measurements made during 1895–1905. It is well defined throughout.

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*Estimated monthly discharge of Kings River near Sanger, Cal., for 1905.*

[Drainage area, 1,742 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 625 | 325 | 447 | 27,480 | 0.257 | 0.29 |
| February | 1,235 | 652 | 899 | 49,930 | .516 | .537 |
| March | 2,900 | 1,085 | 1,844 | 113,400 | 1.06 | 1.22 |
| April | 6,010 | 1,685 | 2,731 | 162,500 | 1.57 | 1.75 |
| May | 9,622 | 2,965 | 5,887 | 361,600 | 3.38 | 3.90 |
| June | 9,795 | 3,770 | 6,448 | 383,700 | 3.70 | 4.13 |
| July | 3,535 | 772 | 1,859 | 114,300 | 1.07 | 1.23 |
| August | 710 | 280 | 448 | 27,550 | .257 | .296 |
| September | 280 | 150 | 198 | 11,780 | .114 | .127 |
| October | 260 | 150 | 174 | 10,700 | .100 | .115 |
| November | 280 | 175 | 191 | 11,360 | .110 | .123 |
| December | 302 | 205 | 246 | 15,130 | .141 | .163 |
| The year | 9,795 | 150 | 1,781 | 1,289,000 | 1.02 | 13.89 |

## MISCELLANEOUS MEASUREMENTS IN KINGS RIVER DRAINAGE BASIN.

*North Fork of Kings River.*—This stream enters Kings River from the north about 20 miles above point where the main Kings River leaves the foothills and enters the San Joaquin Valley. A measurement was made 500 feet above its junction with main river and about 50 feet above lower trail crossing on August 22, 1905, by R. S. Hawley.

Width, 16 feet; area, 21 square feet; mean velocity, 1.86 feet per second; discharge, 39 second-feet.

*Converse Creek.*—This stream enters the Kings River 7 miles below the junction of Middle and South forks. A measurement was made 200 feet above its mouth on August 23, 1905, by R. S. Hawley.

Width, 4 feet; area, 1.6 square feet; mean velocity, 0.77 foot per second; discharge, 1.2 second-feet.

*Ten Mile Creek.*—This creek enters Kings River one-half mile below junction of Middle and South forks. A measurement was made on August 23, 1905, 100 feet above its mouth by R. S. Hawley.

Width, 2 feet; area, 1.6 square feet; mean velocity, 0.69 foot per second; discharge, 1.1 second-feet.

*Boulder Creek.*—This stream enters the South Fork of Kings River 5 miles above the junction of the Middle and South forks. A measurement was made on August 25, 1905, 2 miles above its mouth and 100 feet above lower trail crossing by R. S. Hawley.

Width, 6 feet; area, 2.8 square feet; mean velocity, 1.14 feet per second; discharge, 3.2 second-feet.

*Lightning Creek.*—This stream enters the South Fork of Kings River from the south about 10 miles above the junction of the Middle and South forks. An estimate was made of the discharge about 1 mile above its mouth at the trail crossing on August 25, 1905, by R. S. Hawley.

Discharge, 0.60 second-foot.

*Lewis Creek.*—This stream enters the South Fork of Kings River from the north in Kings River Canyon 2 miles below old Cedar Grove Hotel. A measurement was made August 26, 1905, 500 feet above its mouth by R. S. Hawley.

Width, 3 feet; area, 2.7 square feet; mean velocity, 1.00 foot per second; discharge, 2.7 second-feet.

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*South Fork of Kings River.*—This stream is the principal tributary to Kings River. A measurement was made in the lower Kings River Canyon one-fourth mile above the mouth of Lewis Creek on August 26, 1905, by R. S. Hawley.

Width, 52 feet; area, 51 square feet; mean velocity, 2.73 feet per second; discharge, 139 second-feet.

*South Fork of Kings River.*—A measurement was made 700 feet above the mouth of Bubbs Creek on August 26, 1905, by R. S. Hawley.

Width, 35 feet; area, 36 square feet; mean velocity, 1.36 feet per second; discharge, 49 second-feet.

*South Fork of Kings River.*—A measurement was made August 26, 1905, one-fourth mile below the mouth of Bubbs Creek by R. S. Hawley.

Width, 65 feet; area, 68 square feet; mean velocity, 1.46 feet per second; discharge, 99 second-feet.

*Bubbs Creek.*—This is the principal tributary of South Fork of Kings River and joins it at the head of Kings River Canyon. From the measurements made on South Fork of Kings River above and below the junction of Bubbs Creek on August 26, 1905, by R. S. Hawley, the discharge of Bubbs Creek at the mouth was estimated to be 50 second-feet. On account of roughness of stream bed and high velocities in the creek it was impossible to make discharge measurement. (See measurement of South Fork of Kings River above and below mouth of Bubbs Creek.)

*Copper Creek.*—This stream enters the South Fork of Kings River from the north between North Dome and Buck Peak. A measurement was made on August 26, 1905, one-fourth mile above its mouth by R. S. Hawley.

Width, 4 feet; area, 1.0 square foot; mean velocity, 0.82 foot per second; discharge, 0.82 second-foot.

*Roaring River.*—This stream enters South Fork of Kings River from the south, 5 miles below the junction of South Fork and Bubbs Creek. A measurement was made August 26, 1905, 500 feet above its mouth by R. S. Hawley.

Width, 14 feet; area, 11 square feet; mean velocity, 0.87 foot per second; discharge, 9.6 second-feet.

*Sheep Creek.*—This stream enters the South Fork of Kings River from the south one-fourth mile below Cedar Grove Hotel. An estimate was made of the discharge at the mouth August 26, 1905, by R. S. Hawley.

Discharge, 1.8 second-feet.

*Hotel Creek.*—This stream enters South Fork of Kings River from the north at Cedar Grove Hotel. An estimate was made of the discharge at its mouth on August 26, 1905, by R. S. Hawley.

Discharge, 0.20 second-foot.

*Granite Creek.*—This stream enters South Fork of Kings River from the north between North Mountain and North Dome. An estimate was made of the discharge at the mouth August 26, 1905, by R. S. Hawley.

Discharge, 0.50 second-foot.

*Horseshoe Creek.*—This stream enters Middle Fork of Kings River from the south at Simpson Meadow. An estimate was made of the discharge at its mouth on August 28, 1905, by R. S. Hawley.

Discharge, 2.4 second-feet.

*Middle Fork of Kings River.*—This is one of the principal tributaries of Kings River and drains the high Sierra Nevadas in the northeastern portion of its watershed. A measurement was made on August 28, 1905, 50 feet above the mouth of Horseshoe Creek, at the lower end of Simpson Meadow, by R. S. Hawley.

Width, 41 feet; area, 65 square feet; mean velocity, 1.83 feet per second; discharge, 119 second-feet.

*Goddard Creek.*—This stream is the principal tributary of Middle Fork of Kings River, entering it from the north. A measurement was made August 28, 1905, one-fourth mile above its mouth at Simpson Meadow by R. S. Hawley.

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Width, 26 feet; area, 29 square feet; mean velocity, 1.93 feet per second; discharge, 56 second-feet.

*Dougherty Creek.*—This stream enters Middle Fork of Kings River from the south about 1 mile below Simpson Meadow. A measurement was made August 29, 1905, 300 feet above its mouth by R. S. Hawley.

Width, 4 feet; area 4.4 square feet; mean velocity, 0.86 foot per second; discharge, 3.8 second-feet.

*Slide Creek.*—This is a small stream entering Middle Fork of Kings River from the south 3 miles below Simpson Meadow. An estimate of its discharge was made 300 feet above its mouth August 29, 1905, by R. S. Hawley.

Discharge, 0.50 second-foot.

*Crown Creek.*—This stream enters Middle Fork of Kings River in Tehipite Valley one-half mile southwest of Tehipite Dome. An estimate of its discharge was made on August 29, 1905, 500 feet above its mouth, above the trail crossing, by R. S. Hawley.

Discharge, 8.0 second-feet.

*Blue Canyon Creek.*—This stream enters Middle Fork of Kings River 2 miles above Tehipite Dome. An estimate was made of the discharge August 29, 1905, 200 feet above its mouth by R. S. Hawley.

Discharge, 1.4 second-feet.

*Rancheria Creek.*—This stream enters North Fork of Kings River about 4 miles below Cliff Camp. A measurement was made on August 31, 1905, about 4 miles above its mouth and just below its junction with North Fork of Rancheria Creek by R. S. Hawley.

Width, 8 feet; area, 7.2 square feet; mean velocity, 0.78 foot per second; discharge, 5.6 second-feet.

*North Fork of Rancheria Creek.*—This stream joins Rancheria Creek about 4 miles above its mouth. A measurement was made August 31, 1905, 100 feet above its junction with Rancheria Creek, by R. S. Hawley.

Width, 2 feet; area, 1.2 square feet; mean velocity, 2.00 feet per second; discharge, 2.4 second-feet.

*North Fork of Kings River.*—A measurement was made on this stream on August 31, 1905, about one-half mile above Cliff Camp and about 15 miles above its mouth, by R. S. Hawley.

Width, 8.0 feet; area, 12.8 square feet; mean velocity, 0.73 foot per second; discharge, 9.4 second-feet.

*Bear Creek.*—This stream is tributary to North Fork of Kings River through Dinkey Creek. An estimate was made of the discharge of this stream on August 31, 1905, about 2 miles above its junction with Dinkey Creek at trail crossing, by R. S. Hawley.

Discharge, 0.70 second-foot.

*Laurel Creek.*—This stream is tributary to North Fork of Kings River through Bear Creek and Dinkey Creek. An estimate was made of the discharge on August 31, 1905, about one-fourth mile above junction with Bear Creek, by R. S. Hawley.

Discharge, 0.40 second-foot.

*Dinkey Creek.*—This stream is a tributary of North Fork of Kings River from the west. A measurement was made about 1½ miles above the mouth of Bear Creek at Dinkey Meadows on September 1, 1905, by R. S. Hawley.

Width, 6 feet; area, 4 square feet; mean velocity, 0.70 foot per second; discharge, 2.8 second-feet.

## MERCED RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Merced River drains that portion of the western slope of the Sierra Nevada located between the Tuolumne River on the north and the San Joaquin River on the south. Its drainage area is much less than that of the Tuolumne River. It has numerous tributaries, several of which are of considerable size.

The topography of the country in this basin is similar to that of the Tuolumne River, being rough and broken in the upper reaches. In this basin is situated the famous Yosemite

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Valley with its precipitous walls and domes and great waterfalls, which occur on the main stream and its tributaries, which discharge into the valley over precipitous cliffs rising 2,000 to 3,000 feet above the floor of the valley. The formation is of granite which on the upper reaches of the basin above Yosemite Valley is bare, rising in precipitous peaks and domes, and is smoothly marked by glacial action. The middle reaches of the basin are well timbered. The Mariposa grove of big trees is situated in the basin of the South Fork. The timber growth extends well down on the lower elevations to the foothills where the covering is of brush and grass, used extensively for pasturage. Numerous lakes are scattered over the upper portion of the basin. The mean annual precipitation varies from 25 inches in the foothills to 60 inches on the higher elevations, where it falls in the form of snow, which melts in the spring months, except on the extreme higher mountain peaks, where it often remains during the entire year. After leaving the foothills at Merced Falls, where the gaging station is located, canals divert the water for irrigation on lands along the river bottom and in San Joaquin Valley. The surplus water during flood discharge enters San Joaquin River.

### MERCED RIVER IN YOSEMITE VALLEY, CALIFORNIA.

This station was established July 11, 1904, by A. E. Chandler and N. W. Currie. It is located at the wagon bridge, near the Sentinel Hotel.

The channel is straight for a distance of 150 feet above and 50 feet below station. The current is sluggish. The right bank is low and subject to overflow. The left bank is high and above high water. The bed of the stream is composed of coarse gravel and sand, with small bowlders, and is not subject to much change.

Discharge measurements are made from the lower side of the bridge. The initial point for soundings is stream face of abutment on right bank.

The gage is a vertical timber, securely fastened to a masonry abutment on west bank. The bench mark is the heads of two large nails driven into the stream face of the bridge-seat timber on the left abutment; elevation, 14.64 feet above the datum of the gage.

A description of this station, with gage height and discharge data, is contained in Water-Supply Paper No. 134, United States Geological Survey.

*Discharge measurements of Merced River in Yosemite Valley, California, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| June 6 | W. B. Clapp | 93 | 593 | 2.40 | 6.15 | 1,421 |
| June 8 | do | 93 | 626 | 2.58 | 6.45 | 1,617 |
| June 11 | N. W. Currie | 93 | 730 | 3.14 | 6.95 | 2,289 |
| June 12 | do | 93 | 782 | 3.52 | 7.52 | 2,751 |
| June 20 | do | 93 | 730 | 3.07 | 6.92 | 2,240 |
| June 25 | do | 93 | 594 | 2.28 | 6.00 | 1,354 |
| June 28 | do | 90 | 568 | 2.15 | 5.70 | 1,221 |
| July 4 | do | 90 | 518 | 1.90 | 5.40 | 984 |
| July 13 | do | 90 | 448 | 1.44 | 4.80 | 647 |
| July 17 | do | 90 | 396 | .92 | 4.20 | 365 |
| July 31 | do | 92 | 362 | .52 | 3.78 | 190 |
| August 25 | do | 92 | 308 | .30 | 3.40 | 91 |
| October 24 | do | 20 | 10.5 | 1.46 | 3.10 | [a]15.3 |

[a] Wading 400 feet below bridge.



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*Daily gage height, in feet, of Merced River in Yosemite Valley, California, for 1905.*

| Day. | May. | June. | July. | Aug. | Sept. | Oct. | Day. | May. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 6.2 | 5.7 | 3.7 | 3.3 | 3.3 | 17 | ..... | 7.1 | 4.2 | 3.5 | 3.1 | a3.15 |
| 2 | ..... | 6.2 | 5.5 | 3.7 | 3.3 | a3.3 | 18 | ..... | 6.9 | 4.15 | 3.5 | 3.1 | a3.15 |
| 3 | ..... | 6.1 | 5.3 | 3.7 | 3.3 | 3.25 | 19 | ..... | 6.8 | 4.2 | 3.45 | 3.15 | a3.15 |
| 4 | ..... | 5.95 | 5.4 | 3.7 | 3.25 | a3.25 | 20 | ..... | 6.9 | 4.2 | 3.45 | 3.2 | a3.1 |
| 5 | ..... | 5.8 | 5.35 | 3.65 | 3.2 | a3.25 | 21 | ..... | 7.1 | 4.2 | 3.45 | 3.2 | 3.1 |
| 6 | ..... | 6.2 | 5.35 | 3.6 | 3.2 | a3.25 | 22 | ..... | 7.0 | 4.2 | 3.45 | 3.2 | a3.1 |
| 7 | ..... | 6.5 | 5.3 | 3.6 | 3.2 | 3.25 | 23 | 6.8 | 6.5 | 4.2 | 3.45 | 3.3 | a3.1 |
| 8 | ..... | 6.4 | 5.25 | 3.6 | 3.2 | a3.25 | 24 | 6.8 | 6.5 | 4.2 | 3.4 | 3.3 | 3.1 |
| 9 | ..... | 6.2 | 5.5 | 3.7 | 3.2 | a3.2 | 25 | 7.1 | 6.0 | 4.1 | 3.4 | 3.3 | ..... |
| 10 | ..... | 6.55 | 5.5 | 3.7 | 3.2 | 3.2 | 26 | 7.1 | 6.0 | 4.1 | 3.35 | 3.3 | ..... |
| 11 | ..... | 7.0 | 5.3 | 3.7 | 3.2 | a3.2 | 27 | 6.3 | 5.8 | 4.1 | 3.3 | 3.3 | ..... |
| 12 | ..... | 7.5 | 5.1 | 3.6 | 3.15 | 3.2 | 28 | a6.0 | 5.7 | 4.0 | 3.3 | 3.4 | ..... |
| 13 | ..... | 7.45 | 4.8 | 3.6 | 3.1 | a3.2 | 29 | 5.7 | 5.95 | 3.9 | 3.3 | 3.4 | ..... |
| 14 | ..... | 7.35 | 4.5 | 3.5 | 3.1 | 3.15 | 30 | 6.1 | 5.8 | 3.8 | 3.3 | 3.35 | ..... |
| 15 | ..... | 7.3 | 4.35 | 3.5 | 3.1 | 3.15 | 31 | 6.1 | ..... | 3.8 | 3.3 | ..... | ..... |
| 16 | ..... | 7.4 | 4.3 | 3.5 | 3.1 | a3.15 | | | | | | | |

a Gage height estimated.

*Station rating table for Merced River in Yosemite Valley, California, from July 11, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.10 | 15 | 4.10 | 326 | 5.10 | 815 | 6.20 | 1,505 |
| 3.20 | 38 | 4.20 | 368 | 5.20 | 870 | 6.40 | 1,645 |
| 3.30 | 63 | 4.30 | 412 | 5.30 | 925 | 6.60 | 1,795 |
| 3.40 | 90 | 4.40 | 457 | 5.40 | 985 | 6.80 | 1,950 |
| 3.50 | 118 | 4.50 | 504 | 5.50 | 1,045 | 7.00 | 2,110 |
| 3.60 | 147 | 4.60 | 552 | 5.60 | 1,105 | 7.20 | 2,275 |
| 3.70 | 178 | 4.70 | 602 | 5.70 | 1,170 | 7.40 | 2,445 |
| 3.80 | 212 | 4.80 | 653 | 5.80 | 1,235 | | |
| 3.90 | 248 | 4.90 | 706 | 5.90 | 1,300 | | |
| 4.00 | 286 | 5.00 | 760 | 6.00 | 1,365 | | |

NOTE.—The above table is based on 12 discharge measurements made during 1904-5. It is well defined between gage heights 3.1 feet and 6.5 feet.

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*Estimated monthly discharge of Merced River in Yosemite Valley, California, for 1904 and 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| 1904. | | | | |
| July 11–31 | 602 | 286 | 463 | 19,280 |
| August | 552 | 112 | 248 | 15,250 |
| September 1–24 | 412 | 63 | 131 | 6,236 |
| 1905. | | | | |
| May 23–31 | 2,190 | 1,170 | 1,696 | 30,280 |
| June | 2,530 | 1,170 | 1,771 | 105,400 |
| July | 1,170 | 212 | 610 | 37,510 |
| August | 178 | 63 | 123 | 7,563 |
| September | 90 | 15 | 44.4 | 2,642 |
| October 1–24 | 63 | 15 | 35.3 | 1,680 |
| The period | | | | 185,100 |

### MERCED RIVER ABOVE MERCED FALLS, CAL.

The measurement of this stream was undertaken in response to numerous requests from mining and irrigation interests. The midsummer flow of the stream is less than the combined capacity of the irrigation and power canals taking water in the vicinity of Snelling. The station was established April 6, 1901, by H. H. Henderson. It is located 1 mile above Merced Falls.

Both banks are high and rocky and are not subject to overflow. The bed of the stream is composed of gravel and is subject to some change.

Discharge measurements are made from a cable and car.

The gage is a timber bolted to iron stakes driven in the bed of the stream on the left bank. During 1905 the gage was read by Charles Siegfeldt. The bench mark is a three-fourths inch round iron bolt set 10 inches in the slate rock on the right bank of the river; elevation, 69.20 feet above the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 85, 100, and 134 of the United States Geological Survey.

*Discharge measurements of Merced River above Merced Falls, California, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 16 | F. R. S. Buttemer | 179 | 447 | 2.84 | 10.19 | 1,269 |
| April 7 | O. W. Peterson | 184 | 597 | 3.79 | 10.75 | 2,263 |
| May 24 | R. S. Hawley | 265 | 862 | 4.94 | 11.91 | 4,261 |
| June 17 | do | 272 | 797 | 4.56 | 11.65 | 3,632 |
| July 21 | do | 141 | 282 | 1.74 | 9.04 | 490 |
| September 14 | C. H. Lee | 106 | 128 | .43 | 7.82 | 56 |
| October 19 | Hawley and Lee | 104 | 128 | .37 | 7.80 | 48 |
| October 19 | do | 44 | 38 | 1.34 | 7.80 | 51 |
| December 7 | Hawley and Eaton | 65 | 57 | 1.58 | 8.00 | 90 |

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*Daily gage height, in feet, of Merced River above Merced Falls, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 9.2 | 9.2 | 9.5 | 10.15 | 11.55 | 11.45 | 10.4 | 8.6 | 8.0 | 7.85 | 7.85 | 8.1 |
| 2. | 8.95 | 13.45 | 9.6 | 10.2 | 11.2 | 11.35 | 10.25 | 8.5 | 7.95 | 7.8 | 7.8 | 8.1 |
| 3. | 8.85 | 10.75 | 9.7 | 10.3 | 10.95 | 11.35 | 10.15 | 8.5 | 7.95 | 7.9 | 7.85 | 8.0 |
| 4. | 8.8 | 10.45 | 9.8 | 10.4 | 10.8 | 11.2 | 10.05 | 8.45 | 8.0 | 7.8 | 7.8 | 7.95 |
| 5. | 8.7 | 10.8 | 9.8 | 10.5 | 10.7 | 11.05 | 10.05 | 8.4 | 8.05 | 7.9 | 7.8 | 8.0 |
| 6. | 8.7 | 10.35 | 9.75 | 10.6 | 10.6 | 11.2 | 9.95 | 8.4 | 8.0 | 7.9 | 7.8 | 8.0 |
| 7. | 8.7 | 9.85 | 9.8 | 10.7 | 10.7 | 11.45 | 9.95 | 8.35 | 7.9 | 7.9 | 7.8 | 8.0 |
| 8. | 8.7 | 9.65 | 9.85 | 10.7 | 11.05 | 11.45 | 9.9 | 8.35 | 7.9 | 7.9 | 7.8 | 8.0 |
| 9. | 8.7 | 9.5 | 9.85 | 10.7 | 10.85 | 11.35 | 9.95 | 8.4 | 7.9 | 7.9 | 7.8 | 8.0 |
| 10. | 8.7 | 9.4 | 9.85 | 10.75 | 10.65 | 11.35 | 10.0 | 8.3 | 7.9 | 7.9 | 7.85 | 8.0 |
| 11. | 8.7 | 9.3 | 9.85 | 10.6 | 10.6 | 11.6 | 9.9 | 8.35 | 7.9 | 7.9 | 7.85 | 8.0 |
| 12. | 8.65 | 9.25 | 9.8 | 10.4 | 10.5 | 11.95 | 9.8 | 8.4 | 7.9 | 7.8 | 7.9 | 7.9 |
| 13. | 8.6 | 9.1 | 10.95 | 10.3 | 10.6 | 11.85 | 9.7 | 8.4 | 7.9 | 7.8 | 7.8 | 7.9 |
| 14. | 8.6 | 9.1 | 10.6 | 10.25 | 10.85 | 11.75 | 9.55 | 8.35 | 7.85 | 7.85 | 7.8 | 7.9 |
| 15. | 8.6 | 9.1 | 10.25 | 10.4 | 11.35 | 11.7 | 9.35 | 8.3 | 7.8 | 7.85 | 7.8 | 7.95 |
| 16. | 8.7 | 9.1 | 10.15 | 10.6 | 12.05 | 11.7 | 9.25 | 8.25 | 7.85 | 7.8 | 7.85 | 7.95 |
| 17. | 8.7 | 9.3 | 11.3 | 10.5 | 12.7 | 11.6 | 9.1 | 8.2 | 7.85 | 7.8 | 7.85 | 8.0 |
| 18. | 8.6 | 9.3 | 10.7 | 10.55 | 12.5 | 11.45 | 9.1 | 8.2 | 7.85 | 7.8 | 7.85 | 8.1 |
| 19. | 8.7 | 9.3 | 13.55 | 10.8 | 12.25 | 11.4 | 9.05 | 8.15 | 7.85 | 7.8 | 7.85 | 8.1 |
| 20. | 8.7 | 9.35 | 11.75 | 10.55 | 12.35 | 11.3 | 9.0 | 8.1 | 7.8 | 7.8 | 7.9 | 8.05 |
| 21. | 8.9 | 9.35 | 10.9 | 10.4 | 12.25 | 11.3 | 9.0 | 8.1 | 7.8 | 7.8 | 7.9 | 8.1 |
| 22. | 9.05 | 9.3 | 10.55 | 10.35 | 11.95 | 11.3 | 9.0 | 8.1 | 7.8 | 7.85 | 7.9 | 8.05 |
| 23. | 8.9 | 9.25 | 10.3 | 10.35 | 11.8 | 11.05 | 9.0 | 8.1 | 7.75 | 7.9 | 7.9 | 8.05 |
| 24. | 8.85 | 9.25 | 10.3 | 10.55 | 11.9 | 10.85 | 9.0 | 8.1 | 7.8 | 7.85 | 7.9 | 8.0 |
| 25. | 8.85 | 9.3 | 10.25 | 10.8 | 12.05 | 10.65 | 9.0 | 8.1 | 7.7 | 7.85 | 7.9 | 8.0 |
| 26. | 8.8 | 9.4 | 10.3 | 10.85 | 12.05 | 10.6 | 8.9 | 8.1 | 7.7 | 7.85 | 7.9 | 8.0 |
| 27. | 8.75 | 9.4 | 10.45 | 11.0 | 11.65 | 10.55 | 8.9 | 8.1 | 7.8 | 7.85 | 8.0 | 8.0 |
| 28. | 8.7 | 9.4 | 10.2 | 11.4 | 11.4 | 10.45 | 8.85 | 8.1 | 7.8 | 7.85 | 7.95 | 8.05 |
| 29. | 8.7 | ..... | 10.4 | 11.75 | 11.15 | 10.5 | 8.8 | 8.0 | 7.8 | 7.85 | 8.25 | 8.2 |
| 30. | 8.7 | ..... | 10.35 | 11.8 | 11.2 | 10.5 | 8.75 | 8.0 | 7.8 | 7.8 | 8.15 | 8.2 |
| 31. | 8.8 | ..... | 10.2 | ..... | 11.35 | ..... | 8.65 | 8.0 | ..... | 7.8 | ..... | 8.2 |

*Station rating table for Merced River above Merced Falls, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 7.70 | 35 | 9.00 | 465 | 10.30 | 1,570 | 11.60 | 3,570 |
| 7.80 | 50 | 9.10 | 520 | 10.40 | 1,690 | 11.70 | 3,755 |
| 7.90 | 70 | 9.20 | 580 | 10.50 | 1,820 | 11.80 | 3,945 |
| 8.00 | 90 | 9.30 | 645 | 10.60 | 1,955 | 11.90 | 4,140 |
| 8.10 | 115 | 9.40 | 715 | 10.70 | 2,095 | 12.00 | 4,340 |
| 8.20 | 140 | 9.50 | 790 | 10.80 | 2,240 | 12.20 | 4,755 |
| 8.30 | 170 | 9.60 | 870 | 10.90 | 2,390 | 12.40 | 5,200 |
| 8.40 | 200 | 9.70 | 955 | 11.00 | 2,545 | 12.60 | 5,665 |
| 8.50 | 235 | 9.80 | 1,045 | 11.10 | 2,705 | 12.80 | 6,140 |
| 8.60 | 275 | 9.90 | 1,140 | 11.20 | 2,870 | 13.00 | 6,630 |
| 8.70 | 315 | 10.00 | 1,240 | 11.30 | 3,040 | | |
| 8.80 | 360 | 10.10 | 1,345 | 11.40 | 3,215 | | |
| 8.90 | 410 | 10.20 | 1,455 | 11.50 | 3,390 | | |

NOTE.—The above table is based on 9 discharge measurements made during 1905. It is well defined between gage heights 7.8 feet and 12 feet.

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*Estimated monthly discharge of Merced River above Merced Falls, Cal., for 1905.*

[Drainage area, 1,090 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 580 | 275 | 345 | 21,210 | 0.317 | 0.366 |
| February | 7,760 | 520 | 1,105 | 61,370 | 1.01 | 1.05 |
| March | 8,020 | 790 | 1,774 | 109,100 | 1.63 | 1.88 |
| April | 3,945 | 1,400 | 2,050 | 122,000 | 1.88 | 2.10 |
| May | 5,900 | 1,820 | 3,316 | 203,900 | 3.04 | 3.50 |
| June | 4,240 | 1,755 | 2,980 | 177,300 | 2.73 | 3.05 |
| July | 1,690 | 295 | 804 | 49,440 | .738 | .851 |
| August | 275 | 90 | 158 | 9,715 | .145 | .167 |
| September | 102 | 35 | 62.8 | 3,737 | .058 | .065 |
| October | 70 | 50 | 59.0 | 3,628 | .054 | .062 |
| November | 155 | 50 | 66.4 | 3,951 | .061 | .068 |
| December | 140 | 70 | 97.5 | 5,995 | .089 | .103 |
| The year | 8,020 | 35 | 1,068 | 771,300 | .979 | 13.26 |

## YOSEMITE CREEK IN YOSEMITE VALLEY, CALIFORNIA.

This station was established July 9, 1904, by A. E. Chandler and N. W. Currie. It is located at the wagon bridge, about one-half mile from Yosemite, Cal.

The channel is straight for 50 feet above and 100 feet below station. Both banks are above high water. The bed of the stream is composed of small granite fragments and is permanent.

Discharge measurements are made from the lower side of the bridge. The initial point for soundings is the stream face of the abutment on the right bank.

The gage is a vertical timber securely fastened to an alder tree on the right bank 50 feet above bridge. The bench mark is the heads of two nails driven in the alder tree, to which the gage is fastened. Elevation, 9.40 feet above the datum of the gage.

A description of this station, with gage height and discharge data, is contained in Water-Supply Paper No. 134, United States Geological Survey.

*Discharge measurements of Yosemite Creek in Yosemite Valley, California, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| June 7 | W. B. Clapp | 39 | 106 | 2.19 | 0.05 | 232 |
| June 13 | N. W. Currie | 37 | 122 | 2.39 | 6.55 | 290 |
| June 19 | do | 40 | 100 | 2.8 | 5.78 | 208 |
| June 24 | do | 35 | 82 | 1.72 | 5.40 | 141 |
| June 27 | do | 35 | 76 | 1.54 | 5.15 | 117 |
| July 4 | do | 33 | 57 | 1.16 | 4.75 | 66 |
| July 14 | do | 31 | 42 | .71 | 4.30 | 30 |
| July 23 | do | 29 | 35 | .42 | 4.10 | 14.7 |
| August 1 | do | 28 | 29 | .08 | 3.90 | 2.3 |

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*Daily gage height, in feet, of Yosemite Creek in Yosemite Valley, California, for 1905.*

| Day. | May. | June. | July. | Aug. | Sept. | Oct. | Day. | May. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 6.3 | 5.0 | 3.9 | 3.7 | 3.7 | 17 | | 6.0 | 4.2 | 3.79 | 3.7 | a3.65 |
| 2 | | 6.4 | 4.9 | 3.7 | 3.7 | a3.7 | 18 | | 5.9 | 4.2 | 3.79 | a3.7 | a3.65 |
| 3 | | 6.3 | 4.8 | 3.85 | 3.7 | 3.65 | 19 | | 5.78 | 4.2 | 3.75 | a3.7 | a3.65 |
| 4 | | 5.95 | 4.75 | 3.85 | 3.7 | a3.65 | 20 | | 5.75 | 4.2 | 3.75 | a3.7 | a3.65 |
| 5 | | 5.8 | 4.75 | 3.85 | 3.7 | a3.65 | 21 | | 5.9 | 4.18 | 3.75 | a3.7 | 3.65 |
| 6 | | 5.9 | 4.75 | 3.8 | 3.7 | a3.65 | 22 | | 5.7 | 4.15 | 3.75 | 3.65 | a3.65 |
| 7 | | 6.2 | 4.7 | 3.8 | 3.7 | 3.65 | 23 | 6.7 | 5.4 | 4.1 | 3.75 | a3.65 | a3.65 |
| 8 | | 6.1 | 4.7 | 3.7 | 3.7 | a3.65 | 24 | 6.7 | 5.4 | 4.1 | 3.75 | 3.65 | 3.65 |
| 9 | | 6.0 | 4.75 | 3.8 | 3.7 | a3.65 | 25 | 6.8 | 5.25 | 4.0 | 3.75 | a3.65 | |
| 10 | | 6.5 | 4.7 | 3.8 | 3.7 | a3.65 | 26 | 6.8 | 5.3 | 4.0 | 3.75 | a3.65 | |
| 11 | | 6.3 | 4.6 | 3.8 | 3.7 | a3.65 | 27 | 6.3 | 5.15 | 4.0 | 3.72 | a3.65 | |
| 12 | | 6.4 | 4.5 | 3.8 | a3.7 | a3.65 | 28 | 6.2 | 5.0 | 3.95 | 3.7 | 3.7 | |
| 13 | | 6.55 | 4.4 | 3.78 | 3.7 | a3.65 | 29 | 6.0 | 5.2 | 3.95 | 3.7 | a3.7 | |
| 14 | | 6.35 | 4.3 | 3.8 | 3.7 | 3.65 | 30 | 6.3 | 5.0 | 3.9 | 3.7 | 3.7 | |
| 15 | | 6.35 | 4.25 | 3.8 | 3.7 | a3.65 | 31 | 6.3 | | 3.9 | 3.7 | | |
| 16 | | 6.35 | 4.25 | 3.79 | 3.7 | a3.65 | | | | | | | |

a Estimated.

*Station rating table for Yosemite Creek in Yosemite Valley, California, from July 1, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.70 | 2 | 4.60 | 50 | 5.50 | 150 | 6.40 | 280 |
| 3.80 | 3 | 4.70 | 59 | 5.60 | 163 | 6.50 | 296 |
| 3.90 | 5 | 4.80 | 69 | 5.70 | 177 | 6.60 | 312 |
| 4.00 | 8 | 4.90 | 79 | 5.80 | 191 | 6.70 | 328 |
| 4.10 | 14 | 5.00 | 90 | 5.90 | 205 | 6.80 | 344 |
| 4.20 | 20 | 5.10 | 101 | 6.00 | 220 | 6.90 | 360 |
| 4.30 | 27 | 5.20 | 113 | 6.10 | 235 | 7.00 | 377 |
| 4.40 | 34 | 5.30 | 125 | 6.20 | 250 | | |
| 4.50 | 42 | 5.40 | 137 | 6.30 | 265 | | |

NOTE.—The above table is based on 11 discharge measurements made during 1904-5. It is well defined.

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*Estimated monthly discharge of Yosemite Creek in Yosemite Valley, California, for 1904 and 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| 1904. | | | | |
| July 11 to 31 | 59 | 8 | 32.2 | 1,341 |
| August | 59 | 3 | 9.9 | 609 |
| September 1 to 24 | 50 | 2.5 | 4.7 | 224 |
| 1905. | | | | |
| May 23 to 31 | 344 | 220 | 290 | 5,177 |
| June | 304 | 90 | 206 | 12,260 |
| July | 90 | 5 | 34.3 | 2,109 |
| August | 5 | 2 | 2.8 | 172 |
| September | 2 | 1.5 | 1.9 | 113 |
| October 1 to 24 | 2 | 1.5 | 1.5 | 71 |
| The period | | | | 19,900 |

### TENAYA CREEK IN YOSEMITE VALLEY, CALIFORNIA.

This station was established July 11, 1904, by A. E. Chandler and N. W. Currie. It is located by the wagon bridge, about 2 miles from Yosemite, Cal.

The channel is straight for 200 feet above and below the station. Both banks are above high water. The bed of the stream is composed of small granite fragments and is not subject to change.

Discharge measurements are made from the bridge. The initial point for soundings is the stream face of the abutment on the right bank.

The gage is a vertical timber securely fastened to the bridge stringer on upper side of bridge, 9 feet from left abutment. The bench mark is formed by the heads of two nails in the top of the bridge stringer near the gage; elevation, 12.70 feet above the datum of the gage.

A description of this station, with gage height and discharge data, is contained in Water-Supply Paper No. 134, United States Geological Survey.

*Discharge measurements of Tenaya Creek in Yosemite Valley, California, in 1905.*

| Date. | Hydrographer | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| June 7 | W. B. Clapp | 45 | 119 | 3.36 | 5.95 | 400 |
| June 14 | N. W. Currie | 45 | 125 | 3.42 | 6.00 | 428 |
| June 19 | do | 45 | 110 | 3.03 | 5.65 | 333 |
| June 24 | do | 45 | 90 | 2.46 | 5.18 | 221 |
| June 28 | do | 45 | 72 | 2.01 | 4.80 | 145 |
| July 5 | do | 42 | 51 | 1.59 | 4.40 | 81 |
| July 12 | do | 41 | 37 | 1.19 | 4.10 | 44 |
| July 24 | do | 34 | 16.8 | .84 | 3.60 | 14.1 |
| October 1[a] | do | | | | 3.35 | 3 |

[a] Estimated.

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*Daily gage height, in feet, of Tenaya Creek in Yosemite Valley, California, for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Day. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.9 | 4.7 | 3.5 | 3.35 | 3.35 | 17 | 5.8 | 3.85 | 3.38 | 3.35 | a 3.35 |
| 2 | 5.9 | 4.6 | 3.5 | 3.35 | a 3.35 | 18 | 5.75 | 3.8 | 3.38 | a 3.35 | a 3.35 |
| 3 | 5.9 | 4.5 | 3.5 | 3.35 | a 3.35 | 19 | 5.65 | 3.75 | 3.38 | a 3.35 | a 3.35 |
| 4 | 5.7 | 4.4 | 3.45 | 3.35 | a 3.35 | 20 | 5.55 | 3.7 | 3.38 | a 3.35 | a 3.35 |
| 5 | 5.6 | 4.4 | 3.45 | 3.35 | a 3.35 | 21 | 5.55 | 3.7 | 3.38 | a 3.35 | 3.35 |
| 6 | 5.7 | 4.35 | 3.4 | 3.35 | a 3.35 | 22 | 5.5 | 3.65 | 3.38 | a 3.35 | ..... |
| 7 | 6.0 | 4.3 | 3.4 | 3.35 | 3.35 | 23 | 5.3 | 3.6 | 3.38 | 3.35 | ..... |
| 8 | 5.8 | 4.25 | 3.4 | 3.35 | a 3.35 | 24 | 5.18 | 3.6 | 3.38 | 3.35 | ..... |
| 9 | 5.75 | 4.2 | 3.4 | 3.35 | a 3.35 | 25 | 5.1 | 3.6 | 3.38 | a 3.35 | ..... |
| 10 | 6.0 | 4.1 | 3.4 | 3.35 | 3.35 | 26 | 5.0 | 3.55 | 3.38 | a 3.35 | ..... |
| 11 | 6.01 | 4.1 | 3.38 | 3.35 | a 3.35 | 27 | 4.9 | 3.55 | 3.38 | a 3.35 | ..... |
| 12 | 6.0 | 4.1 | 3.38 | 3.35 | a 3.35 | 28 | 4.83 | 3.55 | 3.38 | a 3.35 | ..... |
| 13 | 6.15 | 4.0 | 3.38 | 3.35 | a 3.35 | 29 | 4.8 | 3.5 | 3.35 | a 3.35 | ..... |
| 14 | 5.98 | 3.95 | 3.38 | 3.35 | 3.35 | 30 | 4.7 | 3.5 | 3.35 | 3.35 | ..... |
| 15 | 5.95 | 3.9 | 3.38 | 3.35 | 3.35 | 31 | ..... | 3.5 | 3.35 | ..... | ..... |
| 16 | 5.9 | 3.85 | 3.38 | 3.35 | a 3.35 | | | | | | |

a Gage heights estimated.

*Station rating table for Tenaya Creek in Yosemite Valley, California, from July 1, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.40 | 4.5 | 4.20 | 54 | 5.00 | 184 | 5.80 | 368 |
| 3.50 | 8 | 4.30 | 66 | 5.10 | 204 | 5.90 | 395 |
| 3.60 | 12 | 4.40 | 80 | 5.20 | 225 | 6.00 | 422 |
| 3.70 | 17 | 4.50 | 95 | 5.30 | 247 | 6.10 | 450 |
| 3.80 | 22 | 4.60 | 111 | 5.40 | 270 | 6.20 | 480 |
| 3.90 | 28 | 4.70 | 128 | 5.50 | 293 | 6.30 | 512 |
| 4.00 | 35 | 4.80 | 146 | 5.60 | 317 | | |
| 4.10 | 44 | 4.90 | 165 | 5.70 | 342 | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on 11 discharge measurements made during 1904–5. It is well defined between gage heights 3.3 feet and 6 feet.

*Estimated monthly discharge of Tenaya Creek in Yosemite Valley, California, for 1904 and 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| 1904. | | | | |
| July 11–31 | 80 | 17 | 38.3 | 1,595 |
| August | 28 | 4.5 | 12.3 | 756 |
| September 1–24 | 80 | 3.9 | 8.6 | 409 |
| 1905. | | | | |
| May 23–31 | 512 | 368 | 425 | 7,587 |
| June | 465 | 128 | 323 | 19,220 |
| July | 128 | 8 | 38.8 | 2,386 |
| August | 8 | 3 | 4.4 | 270 |
| September | 3 | 3 | 3.0 | 179 |
| October 1–21 | 3 | 3 | 3.0 | 125 |
| The period | | | | 29,770 |

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### MISCELLANEOUS MEASUREMENTS IN MERCED RIVER DRAINAGE BASIN.

*Bridal Veil Creek, Yosemite Valley, California.*—This stream is a tributary of the Merced River. An estimate was made of the discharge at a point 500 feet above its junction with Merced River and about 1,000 feet below Bridal Veil Falls on June 7, 1905, by W. B. Clapp. It was impossible to make a measurement on account of the rough bed and heavy grade of the stream.

Estimated discharge, 100 second-feet.

*Cascade Creek, Yosemite Valley, California.*—This stream is a tributary of the Merced River. An estimate was made of the discharge at a point 500 feet below Cascade Falls near mouth of creek on June 6, 1905, by W. B. Clapp.

Estimated discharge, 150 second-feet.

*Ribbon Falls Creek, Yosemite Valley, California.*—This stream is tributary to Merced River in Yosemite Valley. A measurement was made where the creek crosses the road on the west side of the valley on June 7 by W. B. Clapp.

The stream was flowing in several shallow channels.

Total width, 20.5 feet; area, 9.0 square feet; mean velocity, 1.89 feet per second; discharge, 17.0 second-feet.

## TUOLUMNE RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Tuolumne River rises on the western slope of the Sierra Nevada and drains the country located between Stanislaus River on the north and Merced River on the south. It has numerous tributaries, several of which produce a heavy discharge. The country throughout this basin is rough and rugged, especially along the main river, which cuts through solid granite, with high precipitous cliffs on either side. Along this stream is found some of the grandest scenery of the Sierra Nevada. This stream drains the northern portion of the Yosemite National Park, where is located the Grand Canyon of the Tuolumne and the Hetch Hetchy Valley, which is pronounced by many to exceed the famed Yosemite Valley in grandeur and beauty. The formation is of granite, which on the higher elevations is bare and glaciated, often rising thousands of feet in vertical cliffs and domes. Along the middle reaches of this basin there is good soil covering, with a heavy timber growth of pine, fir, cedar, and other kindred trees. On the lower reaches the covering is a heavy growth of brush, which diminishes in the foothills where the stream enters the San Joaquin Valley. This portion of the basin has a light soil covering, with grass growth, which is used for pasturage. There are several glacial lakes throughout the upper reaches of this basin, many of the larger of which offer exceptional opportunities for the construction of storage reservoirs. There are also many reservoir sites on the main river. The stream has a heavy fall, and the opportunities for power development are numerous. Several diversions are made above the gaging station, which is located at Lagrange, where the stream breaks from the foothills. The precipitation on the upper half of this basin falls in the form of snow, a greater portion of which disappears in the spring months, but on the higher elevations remains until late in the summer. The mean annual rainfall varies from about 30 inches on the lower foothills to about 60 inches on the higher elevations.

### TUOLUMNE RIVER AT LAGRANGE, CAL.

This station was established August 29, 1895, by J. B. Lippincott. It is located at the wagon bridge, in the town of Lagrange. It is below the high dam, where the diversions are made by the Turlock and Modesto canals, and also below the head of the canal of the Lagrange Ditch and Hydraulic Mining Company, which diverts water from the left bank of the river above the dam.

The channel is straight for 400 feet above and 600 feet below the station. It is broken by two iron piers and has a width at ordinary stages of 300 feet. During the season of

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low flow all the water is taken out by the Turlock and Modesto canals above the station. The record of flow of these canals is kept. The bed of the stream is composed of gravel and is fairly permanent. The current is swift at high stages and very sluggish during low water. The discharge has gradually increased each year for the same gage heights. Both banks are high and not subject to overflow.

Discharge measurements are made from the downstream side of the bridge. The initial point for soundings is a mark on the railing of the bridge 100 feet north from the center of first pier on right bank of the river.

The gage is a vertical timber fastened to the right abutment of the bridge. During 1905 the gage was read by R. A. Trumbly. Bench marks were established as follows: (1) Top of a rock marked with white paint, situated on the left bank below the bridge and opposite the 573 foot mark of the cross section; elevation, 19.10 feet. (2) The top of rock marked with white paint, situated 75 feet downstream from bench mark No. 1; elevation, 16.89 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 85, 100, and 134 of the United States Geological Survey.

*Discharge measurements of Tuolumne River at Lagrange, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 15 | F. R. S. Buttemer | 325 | 1,426 | 1.79 | 6.10 | 2,548 |
| April 6 | O. W. Patterson | 332 | 1,591 | 2.40 | 6.60 | 3,817 |
| May 24 | R. S. Hawley | 344 | 2,068 | 3.79 | 7.90 | 7,846 |
| June 16 | do | 344 | 2,068 | 3.66 | 7.90 | 7,574 |
| June 17 | do | 344 | 1,906 | 3.28 | 7.45 | 6,249 |
| September 13 | C. H. Lee | 30 | 20 | .45 | 3.30 | 9.2 |
| October 18 | Lee and Hawley | 38 | 36 | 1.47 | 3.68 | 53 |

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*Daily gage height, in feet, of Tuolumne River at Lagrange, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.7 | 5.75 | 5.7 | 5.9 | 7.3 | 7.0 | 6.05 | 3.2 | 3.1 | 3.7 | 3.65 | 4.05 |
| 2 | 5.1 | 8.1 | 5.85 | 6.05 | 6.7 | 7.0 | 6.0 | 3.2 | 3.1 | 3.85 | 3.65 | 4.05 |
| 3 | 5.0 | 6.3 | 5.9 | 5.9 | 6.3 | 6.9 | 5.8 | 3.2 | 3.1 | 3.8 | 3.65 | 4.0 |
| 4 | 4.8 | 6.0 | 5.9 | 5.9 | 6.35 | 6.85 | 5.45 | 3.2 | 3.1 | 3.7 | 3.65 | 4.0 |
| 5 | 4.8 | 6.35 | 5.9 | 5.95 | 6.15 | 6.75 | 5.5 | 3.2 | 3.1 | 3.6 | 3.65 | 4.0 |
| 6 | 4.8 | 6.1 | 5.9 | 6.3 | 6.15 | 6.7 | 5.5 | 3.2 | 3.1 | 3.6 | 3.65 | 4.0 |
| 7 | 4.75 | 5.6 | 5.9 | 6.65 | 6.35 | 6.85 | 5.35 | 3.2 | 3.1 | 3.6 | 3.65 | 4.0 |
| 8 | 4.75 | 5.5 | 5.9 | 6.6 | 6.5 | 7.1 | 5.4 | 3.2 | 3.1 | 3.6 | 3.65 | 4.0 |
| 9 | 4.75 | 5.4 | 5.85 | 6.45 | 6.2 | 7.6 | 5.15 | 3.2 | 3.1 | 3.5 | 3.65 | 4.0 |
| 10 | 4.75 | 5.4 | 5.8 | 6.5 | 6.1 | 7.9 | 5.0 | 3.2 | 3.1 | 3.5 | 3.65 | 4.0 |
| 11 | 4.8 | 5.2 | 5.85 | 6.4 | 6.0 | 8.0 | 4.85 | 3.2 | 3.1 | 3.5 | 3.65 | 3.9 |
| 12 | 4.8 | 5.1 | 5.8 | 6.05 | 6.0 | 8.05 | 4.7 | 3.2 | 3.4 | 3.5 | 3.65 | 3.9 |
| 13 | 4.8 | 5.1 | 6.95 | 5.8 | 5.9 | 8.0 | 4.55 | 3.2 | 3.3 | 3.5 | 3.65 | 4.0 |
| 14 | 4.8 | 5.0 | 6.55 | 5.75 | 6.1 | 7.85 | 4.5 | 3.2 | 3.3 | 3.5 | 3.7 | 3.95 |
| 15 | 4.8 | 5.0 | 6.1 | 5.9 | 6.8 | 7.85 | 4.75 | 3.2 | 3.2 | 3.5 | 3.7 | 3.95 |
| 16 | 4.8 | 4.9 | 6.1 | 5.95 | 7.7 | 7.8 | 4.7 | 3.2 | 3.2 | 3.5 | 3.7 | 3.95 |
| 17 | 4.8 | 5.1 | 7.3 | 5.9 | 8.7 | 7.6 | 3.65 | 3.2 | 3.2 | 3.5 | 3.7 | 4.0 |
| 18 | 4.8 | 5.1 | 7.0 | 5.95 | 8.25 | 7.45 | 3.4 | 3.1 | 3.2 | 3.6 | 3.7 | 4.0 |
| 19 | 4.8 | 5.1 | 9.3 | 5.9 | 8.0 | 7.3 | 3.3 | 3.1 | 3.2 | 3.65 | 3.7 | 4.0 |
| 20 | 4.85 | 5.85 | 7.6 | 5.9 | 8.0 | 7.25 | 3.2 | 3.1 | 3.2 | 3.65 | 3.75 | 4.05 |
| 21 | 5.0 | 5.65 | 6.85 | 5.9 | 8.25 | 7.35 | 3.2 | 3.1 | 3.2 | 3.7 | 3.8 | 4.15 |
| 22 | 5.1 | 5.4 | 6.6 | 5.95 | 7.9 | 6.9 | 3.2 | 3.1 | 3.2 | 3.7 | 3.75 | 4.1 |
| 23 | 5.15 | 5.4 | 6.5 | 6.6 | 7.6 | 6.25 | 3.2 | 3.1 | 3.2 | 3.7 | 3.75 | 4.05 |
| 24 | 5.2 | 5.4 | 6.3 | 7.1 | 7.8 | 6.15 | 3.2 | 3.1 | 3.2 | 3.7 | 3.75 | 4.05 |
| 25 | 5.1 | 5.55 | 6.1 | 7.1 | 8.0 | 6.15 | 3.2 | 3.1 | 3.2 | 3.7 | 3.8 | 4.05 |
| 26 | 5.0 | 5.8 | 6.1 | 7.2 | 7.85 | 6.1 | 3.2 | 3.1 | 3.2 | 3.7 | 3.8 | 4.0 |
| 27 | 4.85 | 5.7 | 6.2 | 7.2 | 7.65 | 6.05 | 3.2 | 3.1 | 3.3 | 3.7 | 3.85 | 4.0 |
| 28 | 4.8 | 5.8 | 6.1 | 7.35 | 7.35 | 6.05 | 3.2 | 3.1 | 3.25 | 3.7 | 4.0 | 4.1 |
| 29 | 4.8 | ..... | 6.45 | 7.4 | 6.7 | 6.20 | 3.2 | 3.1 | 3.4 | 3.65 | 4.0 | 4.15 |
| 30 | 4.9 | ..... | 6.25 | 7.7 | 6.85 | 6.05 | 3.2 | 3.1 | 3.5 | 3.65 | 4.05 | 4.15 |
| 31 | 4.9 | ..... | 6.1 | ..... | 6.9 | ..... | 3.2 | 3.1 | ..... | 3.65 | ..... | 4.2 |

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*Station rating table for Tuolumne River at Lagrange, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.10 | 1 | 4.50 | 340 | 5.90 | 2,200 | 7.60 | 6,700 |
| 3.20 | 5 | 4.60 | 410 | 6.00 | 2,400 | 7.80 | 7,360 |
| 3.30 | 10 | 4.70 | 490 | 6.10 | 2,610 | 8.00 | 8,060 |
| 3.40 | 20 | 4.80 | 580 | 6.20 | 2,830 | 8.20 | 8,780 |
| 3.50 | 30 | 4.90 | 680 | 6.30 | 3,060 | 8.40 | 9,500 |
| 3.60 | 40 | 5.00 | 790 | 6.40 | 3,300 | 8.60 | 10,260 |
| 3.70 | 55 | 5.10 | 910 | 6.50 | 3,550 | 8.80 | 11,050 |
| 3.80 | 70 | 5.20 | 1,030 | 6.60 | 3,800 | 9.00 | 11,850 |
| 3.90 | 90 | 5.30 | 1,170 | 6.70 | 4,060 | 9.20 | 12,660 |
| 4.00 | 120 | 5.40 | 1,310 | 6.80 | 4,320 | 9.40 | 13,490 |
| 4.10 | 150 | 5.50 | 1,470 | 6.90 | 4,600 | 9.60 | 14,320 |
| 4.20 | 190 | 5.60 | 1,630 | 7.00 | 4,880 | 9.80 | 15,160 |
| 4.30 | 230 | 5.70 | 1,810 | 7.20 | 5,470 | 10.00 | 16,000 |
| 4.40 | 280 | 5.80 | 2,000 | 7.40 | 6,070 | | |

*Estimated monthly discharge of Tuolumne River at Lagrange, Cal., for 1905.*

[Drainage area, 1,501 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 1,810 | 535 | 745 | 45,810 | 0.496 | 0.572 |
| February | 8,420 | 745 | 1,926 | 107,000 | 1.28 | 1.33 |
| March | 13,070 | 1,871 | 3,487 | 214,400 | 2.32 | 2.68 |
| April | 7,770 | 2,696 | 4,016 | 239,000 | 2.68 | 2.99 |
| May | 11,360 | 2,866 | 5,927 | 364,400 | 3.95 | 4.55 |
| June | 9,075 | 3,258 | 5,969 | 355,200 | 3.98 | 4.44 |
| July | 3,403 | 427 | 1,344 | 82,640 | .895 | 1.03 |
| August | 345 | 103 | 212 | 13,040 | .141 | .163 |
| September | 131 | [a] 8 | 78.1 | 4,647 | .052 | .058 |
| October | 80 | 30 | 45.5 | 2,798 | .030 | .035 |
| November | 135 | 48 | 62.2 | 3,701 | .041 | .046 |
| December | 190 | 90 | 129 | 7,932 | .086 | .099 |
| The year | 13,070 | 8 | 1,995 | 1,441,000 | 1.33 | 17.99 |

[a] The minimum of 8 feet in September was caused by closing head-gate of Turlock Canal and holding water back in reservoir until dam overflowed.

NOTE.—The above discharge includes that of Turlock and Modesto canals.

### MODESTO CANAL AT LAGRANGE, CAL.

The Modesto canal is the property of the Modesto irrigation district. The water is diverted from the right side of the Tuolumne River at the Lagrange dam. This canal was designed to carry 660 second-feet and to irrigate land in the vicinity of Modesto, Stanislaus County, Cal. The principal part of the construction work was done on this canal prior to 1892, but on account of litigation the canal was not completed until April, 1903.

On April 26, 1903, a gage rod was set in and a rating made of Indian Hill flume, near Lagrange, Cal. From May 10 to June 3 and from June 10 to June 25, inclusive, boards were placed in the flumes to back the water up and keep the flumes saturated. During this time gage heights were obtained by taking the depth of the water in the canal below Indian Hill flume.

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On July 12, 1904, the station was moved to the flume near the intake. This was done so that more gage readings and explanations of their fluctuations could be obtained by having J. L. Montgomery, the regulator of the gates at the intake, act as gage observer. This flume is 11.85 feet in width.

Information in regard to this station is contained in Water-Supply Papers Nos. 100 and 134 of the United States Geological Survey.

*Discharge measurements of Modesto canal at Lagrange, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| April 6 | O. W. Peterson | 11.8 | 40 | 7.28 | 3.40 | 291 |
| May 24 | R. S. Hawley | 11.8 | 37 | 6.68 | 3.15 | 247 |
| June 17 | do | 11.8 | 45 | 7.18 | 3.85 | 323 |
| July 21 | do | 12 | 35 | 6.34 | 2.95 | 222 |

*Daily gage height, in feet, of Modesto canal at Lagrange, Cal., for 1905.*

| Day. | Jan | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 2.8 | a 1.2 | 2.6 | 3.0 | 3.5 | 4.0 | 1.7 | 1.0 |
| 2 | 0 | b 0 | 1.2 | 2.9 | 3.0 | 3.5 | 4.0 | 1.8 | .95 |
| 3 | 0 | a 1.3 | 1.2 | 3.1 | 3.0 | 3.5 | b 0 | 1.8 | .95 |
| 4 | 0 | 2.0 | 1.2 | 3.2 | 3.0 | 3.5 | a 2.5 | 1.6 | .95 |
| 5 | 0 | 2.1 | 1.2 | 3.3 | 3.0 | 3.5 | 3.5 | 1.65 | .95 |
| 6 | 0 | 2.0 | 1.25 | 3.3 | 3.0 | 3.5 | 4.0 | 1.65 | .8 |
| 7 | 0 | 1.95 | 1.25 | 3.3 | 3.0 | 3.6 | 4.0 | 1.4 | .85 |
| 8 | 0 | 2.45 | 1.25 | 3.2 | 3.0 | 3.6 | 4.0 | 1.55 | .8 |
| 9 | 0 | 2.8 | 1.25 | 3.2 | 3.0 | 3.6 | 4.5 | 1.55 | .8 |
| 10 | 0 | 3.0 | 1.25 | 3.1 | 3.0 | 3.6 | 4.5 | 1.4 | .8 |
| 11 | 0 | 3.0 | 1.25 | 3.2 | 3.0 | 2.5 | 4.5 | 1.5 | .4 |
| 12 | 0 | 3.1 | .85 | 3.2 | 3.0 | 3.5 | 4.0 | 1.4 | ..... |
| 13 | 0 | 3.2 | .5 | 3.2 | 3.0 | 2.75 | 4.0 | 1.4 | ..... |
| 14 | 0 | 3.3 | .7 | 3.1 | 3.0 | 3.7 | 4.0 | 1.4 | ..... |
| 15 | 0 | 3.3 | .7 | 3.0 | 3.0 | 3.7 | 4.0 | 1.3 | ..... |
| 16 | a 1.0 | 3.3 | .7 | 3.0 | 3.0 | 3.7 | 4.0 | 1.3 | ..... |
| 17 | .9 | 3.3 | .8 | 3.0 | 3.0 | 3.7 | 4.0 | 1.3 | ..... |
| 18 | .9 | 3.3 | .8 | 3.0 | 3.0 | 3.75 | 4.0 | 1.3 | ..... |
| 19 | .9 | 3.3 | b 0 | 3.0 | 3.0 | 3.75 | 3.0 | 1.25 | ..... |
| 20 | .9 | 3.0 | 0 | 3.0 | 3.2 | 3.75 | 3.0 | 1.0 | ..... |
| 21 | 1.05 | 2.7 | 0 | 3.0 | 3.2 | 3.8 | 2.9 | 1.1 | ..... |
| 22 | 1.05 | 3.3 | a 2.0 | 3.0 | b 0 | 3.9 | 2.9 | 1.15 | ..... |
| 23 | 1.05 | 3.0 | 2.1 | 3.0 | 0 | 3.9 | 2.5 | 1.15 | ..... |
| 24 | 1.05 | 2.75 | 2.5 | 3.0 | a 3.15 | 4.0 | 2.5 | 1.15 | ..... |
| 25 | 1.05 | 2.75 | 2.5 | 3.0 | 3.3 | 1.75 | 2.75 | 1.15 | ..... |
| 26 | 1.6 | b 0 | 2.8 | 3.0 | 3.35 | 1.55 | 2.7 | 1.15 | ..... |
| 27 | 2.0 | 0 | b 0 | 3.0 | 3.35 | 4.0 | 2.55 | 1.1 | ..... |
| 28 | 2.05 | 0 | 0 | 3.0 | 3.5 | 4.0 | 2.4 | .9 | ..... |
| 29 | 2.05 | ..... | 0 | 3.0 | 3.5 | 4.0 | 2.55 | .9 | ..... |
| 30 | 2.35 | ..... | a 1.5 | 3.0 | 3.5 | 4.0 | 2.1 | .9 | ..... |
| 31 | 2.7 | ..... | 2.0 | ..... | 3.5 | ..... | 2.1 | 1.0 | ..... |

a Water turned in. b Water turned out.

NOTE.—Canal dry September 12 to December 31.

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*Station rating table for Modesto canal at Lagrange, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.10 | 2 | 1.10 | 53 | 2.10 | 140 | 3.20 | 252 |
| 20 | 4 | 1.20 | 61 | 2.20 | 150 | 3.40 | 274 |
| 30 | 7 | 1.30 | 69 | 2.30 | 160 | 3.60 | 296 |
| 40 | 11 | 1.40 | 77 | 2.40 | 170 | 3.80 | 318 |
| 50 | 16 | 1.50 | 85 | 2.50 | 180 | 4.00 | 340 |
| 60 | 21 | 1.60 | 94 | 2.60 | 190 | 4.20 | 364 |
| 70 | 26 | 1.70 | 103 | 2.70 | 200 | 4.40 | 388 |
| 80 | 32 | 1.80 | 112 | 2.80 | 210 | | |
| 90 | 38 | 1.90 | 121 | 2.90 | 220 | | |
| 1.00 | 45 | 2.00 | 130 | 3.00 | 230 | | |

NOTE.—The above table is based on discharge measurements made during 1904-1905. It is well defined between gage heights 0.5 foot and 4 feet. Monthly estimates are included with those of Tuolumne River, p. 210.

## TURLOCK CANAL AT LAGRANGE, CAL.

The Turlock canal, the property of the Turlock irrigation district, takes water from the left bank of the Tuolumne River at the Lagrange dam. This canal was designed to carry 1,500 second-feet and to irrigate a large area of fertile land in the vicinity of Turlock and Ceres, Stanislaus County, Cal.

During 1898 water was first turned into the canal in small quantities and used for puddling the banks. A record of the gage height has been kept since July, 1899. Meter measurements are made when the gaging station on the Tuolumne River at Lagrange is visited, and Morgan flume, or flume No. 2, has been rated. It is 13.75 feet in width.

In the spring of 1905 a station was established in flume No. 1 and used for some time, but it did not give satisfactory results during high stages of the canal. Gage readings were discontinued on this flume and resumed on the Morgan flume. The record since May 22, 1905, is on the Morgan flume. The observer is J. J. R. Johnson, the canal tender.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 85, 100, and 134 of the United States Geological Survey.

*Discharge measurements of Turlock canal at Lagrange, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| April 8 | O. W. Peterson | 19.5 | 24 | 1.96 | 1.22 | 47 |
| April 8 | do | 19.5 | 40 | 3.20 | 2.05 | 128 |
| April 8 | do | 19.5 | 55 | 3.82 | 2.80 | 210 |
| April 8 | do | 19.5 | 81 | 4.60 | 4.15 | 375 |
| May 24 | R. S. Hawley | 13.8 | 72 | 7.13 | 5.30 | 514 |
| June 17 | do | 13.8 | 76 | 7.58 | 5.55 | 576 |
| July 21 | do | 13.8 | 66 | 6.55 | 4.65 | 432 |
| September 14 | C. H. Lee | 13.6 | 28 | 3.07 | 2.04 | 86 |

NOTE.—Measurements on April 8 were made on little flume near head of canal, others made at Morgan flume.

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*Daily gage height, in feet, of Turlock canal at Lagrange, Cal., for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|
| 1 | ..... | 4.15 | 5.3 | 5.4 | 5.55 | 3.1 | 2.0 |
| 2 | ..... | 4.1 | 5.3 | 5.4 | 5.6 | 3.2 | 2.0 |
| 3 | ..... | 4.1 | 5.4 | 5.4 | 5.6 | 3.15 | 1.9 |
| 4 | ..... | 4.15 | 5.2 | 5.4 | 5.6 | 2.9 | 1.9 |
| 5 | ..... | 4.2 | 5.2 | 5.4 | 5.6 | 2.95 | 1.9 |
| 6 | ..... | 0 | 5.2 | 5.4 | 5.6 | 2.95 | 1.8 |
| 7 | ..... | 0 | 4.1 | 5.4 | 5.6 | 2.65 | 1.8 |
| 8 | ..... | 3.2 | 4.6 | 5.4 | 5.6 | 2.65 | 1.65 |
| 9 | ..... | 3.0 | 4.7 | 5.4 | 5.6 | 2.65 | 1.65 |
| 10 | ..... | 1.5 | 4.7 | 5.45 | 5.6 | 2.65 | 1.65 |
| 11 | ..... | 4.6 | 4.7 | 5.4 | 5.6 | 2.65 | 1.65 |
| 12 | ..... | 4.7 | 4.7 | 5.5 | 5.6 | 2.6 | 1.65 |
| 13 | ..... | 4.8 | 4.7 | 5.5 | 5.6 | 2.7 | 1.8 |
| 14 | ..... | 5.5 | 4.75 | 5.5 | 5.6 | 2.4 | 2.5 |
| 15 | ..... | 5.5 | 4.85 | 5.5 | 3.6 | 2.4 | 2.1 |
| 16 | ..... | 5.5 | 4.9 | 5.5 | 5.6 | 2.4 | 2.1 |
| 17 | ..... | 5.5 | 5.0 | 5.5 | 5.2 | 2.4 | 1.8 |
| 18 | ..... | 5.5 | 5.0 | 5.55 | 5.4 | 2.4 | 1.8 |
| 19 | ..... | 5.2 | 5.0 | 5.5 | 5.0 | 2.4 | 1.7 |
| 20 | ..... | 5.2 | 0 | 5.5 | 5.0 | 2.0 | 1.75 |
| 21 | ..... | 5.3 | 0 | 5.5 | 4.8 | 2.15 | 1.75 |
| 22 | 1.6 | 5.2 | 5.3 | 5.5 | 4.8 | 2.2 | 1.75 |
| 23 | 2.1 | 5.25 | 5.25 | 5.5 | 4.2 | 2.2 | 1.75 |
| 24 | 2.1 | 5.25 | 5.25 | 5.5 | 4.55 | 2.2 | 1.75 |
| 25 | 3.0 | 5.25 | 5.3 | 5.55 | 4.55 | 2.2 | 1.75 |
| 26 | 3.4 | 5.2 | 5.4 | 5.55 | 4.5 | 2.2 | 1.75 |
| 27 | 4.1 | 5.3 | 5.4 | 5.55 | 4.25 | 2.2 | ..... |
| 28 | 4.1 | 5.4 | 5.4 | 5.55 | 4.0 | 1.8 | ..... |
| 29 | 2.1 | 5.3 | 5.4 | 5.6 | 4.1 | 1.8 | ..... |
| 30 | 4.1 | 5.3 | 5.4 | 5.55 | 3.6 | 1.8 | ..... |
| 31 | 4.0 | ..... | 5.4 | ..... | 3.6 | 2.0 | ..... |

NOTE.—Canal dry January 1 to March 21 and September 26 to December 31.

*Station rating table for Turlock canal at Lagrange, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.30 | 1 | 1.50 | 40 | 2.70 | 166 | 3.90 | 324 |
| 40 | 2 | 1.60 | 47 | 2.80 | 178 | 4.00 | 338 |
| 50 | 3 | 1.70 | 55 | 2.90 | 190 | 4.20 | 366 |
| 60 | 4 | 1.80 | 64 | 3.00 | 202 | 4.40 | 394 |
| 70 | 5 | 1.90 | 74 | 3.10 | 215 | 4.60 | 422 |
| 80 | 7 | 2.00 | 85 | 3.20 | 228 | 4.80 | 450 |
| 90 | 10 | 2.10 | 96 | 3.30 | 241 | 5.00 | 478 |
| 1.00 | 14 | 2.20 | 107 | 3.40 | 254 | 5.20 | 506 |
| 1.10 | 18 | 2.30 | 118 | 3.50 | 268 | 5.40 | 535 |
| 1.20 | 23 | 2.40 | 130 | 3.60 | 282 | 5.60 | 565 |
| 1.30 | 28 | 2.50 | 142 | 3.70 | 296 | | |
| 1.40 | 34 | 2.60 | 154 | 3.80 | 310 | | |

NOTE.—The above table is based on discharge measurements made during 1904–5. It is well defined between gage heights 2 feet and 5.5 feet. Monthly estimates are included with those of Tuolumne River, p. 210.

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### MISCELLANEOUS MEASUREMENTS IN TUOLUMNE RIVER DRAINAGE BASIN.

*Clavey River.*—This stream is tributary to Tuolumne River from the north and enters it about 10 miles above the mouth of the North Fork. A measurement was made on September 15, 1905, just above the bridge for the new trail from Tuolumne to Lake Eleanor, by H. A. Campbell.

Width, 10 feet; area, 14.3 square feet; mean velocity, 0.87 foot per second; discharge, 12.5 second-feet.

*Cherry River.*—This stream is tributary to the Tuolumne River from the north and enters it about 15 miles below Hetch Hetchy Valley. A measurement was made one-third of a mile above the mouth of Eleanor Creek on September 16, 1905, by H. A. Campbell.

Width, 2 feet; area, 1.4 square feet; mean velocity, 1.00 foot per second; discharge, 1.4 second-feet.

*Cherry River at Cherry Valley, Cal.*—A measurement was made at the old gaging station in the lower end of Cherry Valley on main trail from Tuolumne to Lake Eleanor on September 17, 1905, by H. A. Campbell.

Width, 2.2 feet; area, 1.6 square feet; mean velocity, 0.58 foot per second; discharge, 0.92 second-foot.

*Eleanor Creek.*—A measurement was made on September 18, 1905, 1 mile below outlet from Lake Eleanor and about 3 miles above its junction with Cherry Creek, by H. A. Campbell.

Width, 2.0 feet; area, 0.50 square foot; mean velocity, 0.60 foot per second; discharge, 0.30 second-foot.

*Tuolumne River at Hetch Hetchy, Cal.*—A measurement was made on September 18, 1905, at the head of Hetch Hetchy Valley, one-half mile above mouth of Rancheria Creek, by H. A. Campbell.

Width, 14 feet; area, 12 square feet; mean velocity, 1.83 feet per second; discharge, 22 second-feet.

*Rancheria Creek.*—This stream enters Tuolumne River from the north in Hetch Hetchy Valley. A measurement was made on September 19, 1905, 100 yards above trail crossing, about 1½ miles above its junction with Tuolumne River, by H. A. Campbell.

Width, 4 feet; area, 3.3 square feet; mean velocity, 0.94 foot per second; discharge, 3.1 second-feet.

*Tiltill Creek.*—This stream enters the Tuolumne River from the north in Hetch Hetchy Valley. A measurement was made on September 19, 1905, at lower end of Tiltill Valley about 2 miles above its junction with Tuolumne River, by H. A. Campbell.

Width, 0.9 foot; area, 0.18 square foot; mean velocity, 0.67 foot per second; discharge, 0.12 second-foot.

*Falls Creek.*—This stream enters Tuolumne River from the north in Hetch Hetchy Valley. A measurement was made on September 19, 1905, at the outlet of Lake Vernon, by H. A. Campbell.

Width, 4.4 feet; area, 1.6 square feet; mean velocity, 0.75 foot per second; discharge, 1.2 second-feet.

*Tuolumne River at Hetch Hetchy Valley, Cal.*—A measurement was made on September 21, 1905, at the lower end of Hetch Hetchy Valley about one-half mile below trail to Lake Eleanor, by H. A. Campbell.

Width, 18.5 feet; area, 13.5 square feet; mean velocity, 1.78 feet per second; discharge, 24 second-feet.

*Middle Fork of Tuolumne River.*—A measurement was made on this stream on September 21, 1905, about 100 yards downstream from the bridge on the road from Sequoia to Hog Ranch by H. A. Campbell.

Width, 2 feet; area, 0.60 square foot; mean velocity, 0.93 foot per second; discharge, 0.56 second-foot.

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*South Fork of Tuolumne River.*—A measurement was made on this stream on September 22, 1905, about 75 yards upstream from the bridge on the Big Oak Flat and Yosemite Toll Road, near Harden ranch, by H. A. Campbell.

Width, 11.2 feet; area, 10.6 square feet; mean velocity, 0.42 foot per second; discharge, 4.5 second-feet.

*Mining ditch near Lagrange, Cal.*—This ditch diverts water from the Tuolumne River several miles above the town of Lagrange, Cal. A measurement was made April 6 at a point on the hill above the Lagrange dam.

Width, 6 feet; area, 4.3 square feet; mean velocity, 1.58 feet per second; discharge, 6.8 second-feet.

## STANISLAUS RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Stanislaus River drains a portion of the western slope of the Sierra Nevada and heads well back on the crest, at elevations of from 10,000 to 12,000 feet. It drains the country between the basins of the Mokelumne River on the north and the Tuolumne River on the south, and flows in a general southwesterly direction, entering the San Joaquin River 23 miles above Stockton. It has numerous tributaries in the upper reaches of the basin, which have their source in numerous small glacial lakes. The topography is rough and broken with high mountain peaks. The formation is of granite, which is bare and destitute of timber growth above an elevation of 8,000 feet, except where small glacial lakes and moraines occur. In the middle reaches of the basin there is good soil covering and a heavy growth of timber. In this basin is situated the Calaveras grove of big trees (*Sequoia gigantea*), for which the Sierra Nevada are famous. This is the most northerly grove of these trees, groves of which extend as far south as the Kern River basin. The mean annual rainfall for the basin is about 50 inches. The precipitation falls chiefly in the form of snow on the higher elevations, remaining well into the summer months. Mining operations have been carried on extensively in this basin, and many canals have been taken out of the river, all of which discharge their water into the river again. The canal of the Stanislaus Water Company diverts water 3 miles above Knights Ferry, which is used to irrigate land between Knights Ferry and Stockton. A gaging station is maintained on this canal to determine its discharge.

### STANISLAUS RIVER AT KNIGHTS FERRY, CAL.

A station was first established on this river on May 3, 1895, at the railroad bridge one-half mile north of the town of Oakdale. On July 30, 1898, a cable was placed 1,000 feet below the railroad bridge. This station was used until February 16, 1901.

The station at Knights Ferry was established May 19, 1903, by W. H. Stearns. It is located 200 feet from the post-office at Knights Ferry.

There is an island 800 feet above the gaging station, and a dam on each channel at the head of the island. The Stanislaus Milling and Power Company's power house is on the right bank of the river below one of these dams and about 1,000 feet above the gaging station. The channel is straight for 500 feet above and below the cable. At ordinary and high stages the stream has a fall of 0.47 foot in the 500 feet above the cable and of 0.68 foot in the 500 feet below. Both banks are composed of cemented gravel and are high. The left bank is not subject to overflow. In extreme floods the right bank has been known to be overflowed, flooding the yards and houses next to the river. The bed is of gravel and is subject to some change from the addition of material which is washed down from the island above.

Discharge measurements at high and medium stages are made from a car suspended from a cable. Low-water measurements are made by wading 300 feet above the cable. The initial point for soundings is the eyebolt to which the cable is fastened on the right bank.



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Ordinary and low-water stages were read on an iron pipe driven into the bed of the stream. For high stages the gage was a plank nailed to a post on the right bank of the river. A new gage rod has been placed near the cable on the right bank and gage readings are now made on this rod. It consists of an inclined rod fastened securely to posts set in the ground. This portion of the rod is used for the lower stages. For high water there is a vertical section similar to the above at the north cable support. During 1905 the gage was read once each day by E. J. Coop. Bench marks were established as follows: (1) A spike in a locust tree 50 feet northeast of right cable support; elevation, 19.20 feet. (2) A rock under the spike at the foot of the above locust tree; elevation, 18.74 feet. Elevations refer to the datum of the new gage.

Information in regard to this station is contained in Water-Supply Papers Nos. 81, 100, and 134 of the United States Geological Survey.

*Discharge measurements of Stanislaus River at Knights Ferry, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 14 | F. R. S. Buttemer | 197 | 751 | 3.36 | 9.15 | 2,523 |
| April 6 | O. W. Peterson | 198 | 769 | 3.49 | 9.25 | 2,687 |
| April 16 | R. S. Hawley | 194 | 771 | 3.27 | 9.30 | 2,518 |
| May 23 | do | 217 | 944 | 4.30 | 10.05 | 4,062 |
| July 20 | do | 148 | 363 | 1.17 | 7.00 | 425 |
| September 12 | Lee and Keeler | 40 | 51 | 1.68 | 6.19 | 86 |
| September 22 | R. W. Keeler | 40 | 49 | 1.57 | 6.11 | 77 |
| September 29 | do | 40 | 49 | 1.63 | 6.17 | 80 |
| October 6 | do | 40 | 49 | 1.69 | 6.14 | 83 |
| October 13 | do | 40 | 48 | 1.77 | 6.19 | 85 |
| October 16 | Lee and Hawley | 40 | 47 | 1.85 | 6.21 | 87 |
| December 21 | R. W. Keeler | 120 | 268 | .53 | 6.41 | 142 |

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*Daily gage height, in feet, of Stanislaus River at Knights Ferry, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.4 | 7.75 | 8.25 | 8.55 | 9.8 | 9.45 | 7.95 | 6.4 | 6.15 | 6.1 | 6.1 | 6.45 |
| 2 | 7.3 | 10.15 | 8.4 | 8.7 | 9.5 | 9.35 | 7.8 | 6.4 | 6.15 | 6.1 | 6.1 | 6.3 |
| 3 | 7.25 | 8.4 | 8.45 | 8.85 | 9.35 | 9.25 | 7.7 | 6.4 | 6.15 | 6.15 | 6.1 | 6.25 |
| 4 | 7.15 | 8.05 | 8.55 | 8.95 | 9.1 | 9.0 | 7.65 | 6.4 | 6.15 | 6.15 | 6.1 | 6.3 |
| 5 | 7.1 | 8.85 | 8.5 | 9.1 | 9.0 | 8.8 | 7.6 | 6.35 | 5.7 | 6.15 | 6.1 | 6.3 |
| 6 | 7.05 | 8.45 | 8.5 | 9.25 | 8.85 | 8.85 | 7.45 | 6.3 | 5.7 | 6.1 | 6.1 | 6.3 |
| 7 | 7.0 | 8.1 | 8.5 | 9.4 | 9.4 | 9.2 | 7.45 | 6.3 | 6.2 | 6.1 | 6.1 | 6.3 |
| 8 | 7.0 | 7.85 | 8.45 | 9.4 | 9.35 | 9.2 | 7.45 | 6.25 | 6.2 | 6.1 | 6.1 | 6.3 |
| 9 | 7.15 | 7.8 | 8.4 | 9.4 | 9.1 | 9.1 | 7.45 | 6.25 | 6.15 | 6.1 | 6.1 | 6.3 |
| 10 | 7.2 | 7.7 | 8.4 | 9.45 | 8.95 | 9.15 | 7.4 | 6.25 | 6.1 | 6.1 | 6.15 | 6.3 |
| 11 | 7.1 | 7.65 | 8.45 | 9.15 | 8.8 | 9.4 | 7.3 | 6.25 | 6.1 | 6.1 | 6.2 | 6.3 |
| 12 | 7.05 | 7.6 | 8.4 | 8.95 | 8.75 | 9.65 | 7.3 | 6.25 | 6.15 | 6.1 | 6.2 | 6.3 |
| 13 | 7.0 | 7.45 | 9.1 | 8.9 | 8.75 | 9.65 | 7.2 | 6.2 | 6.15 | 6.1 | 6.2 | 6.3 |
| 14 | 7.0 | 7.4 | 9.0 | 8.95 | 9.05 | 9.5 | 7.1 | 6.2 | 6.15 | 6.1 | 6.2 | 6.3 |
| 15 | 7.1 | 7.4 | 8.55 | 9.1 | 9.5 | 9.3 | 7.0 | 6.25 | 6.2 | 6.15 | 6.2 | 6.3 |
| 16 | 7.4 | 7.4 | 9.1 | 9.25 | 10.15 | 9.4 | 6.9 | 6.2 | 6.2 | 6.2 | 6.2 | 6.3 |
| 17 | 7.3 | 7.7 | 10.35 | 9.05 | 11.2 | 9.25 | 6.85 | 6.2 | 6.2 | 6.15 | 6.2 | 6.25 |
| 18 | 7.3 | 7.8 | 9.6 | 9.2 | 10.55 | 9.2 | 6.85 | 6.2 | 6.2 | 6.15 | 6.2 | 6.25 |
| 19 | 7.25 | 7.8 | 11.5 | 9.25 | 10.4 | 9.05 | 6.75 | 6.2 | 6.2 | 6.15 | 6.2 | 6.3 |
| 20 | 7.3 | 8.6 | 10.0 | 8.9 | 10.25 | 8.95 | 6.85 | 6.25 | 6.15 | 6.15 | 6.2 | 6.4 |
| 21 | 7.7 | 8.45 | 9.35 | 8.8 | 10.35 | 8.95 | 6.75 | 6.25 | 6.15 | 6.15 | 6.25 | 6.4 |
| 22 | 7.5 | 8.2 | 9.25 | 8.75 | 10.05 | 8.9 | 6.7 | 6.25 | 6.1 | 6.15 | 6.3 | 6.3 |
| 23 | 7.7 | 8.1 | 8.85 | 8.9 | 9.9 | 8.7 | 6.75 | 6.25 | 6.15 | 6.15 | 6.3 | 6.25 |
| 24 | 7.65 | 8.1 | 8.8 | 9.05 | 9.85 | 8.45 | 6.85 | 6.25 | 6.15 | 6.15 | 6.25 | 6.2 |
| 25 | 7.55 | 8.15 | 8.85 | 9.45 | 9.95 | 8.2 | 6.75 | 6.25 | 6.15 | 6.1 | 6.2 | 6.2 |
| 26 | 7.5 | 8.3 | 8.9 | 9.65 | 10.0 | 8.25 | 6.7 | 6.25 | 6.15 | 6.1 | 6.2 | 6.25 |
| 27 | 7.35 | 8.3 | 9.2 | 10.0 | 9.55 | 8.1 | 6.65 | 6.25 | 6.15 | 6.1 | 6.3 | 6.3 |
| 28 | 7.3 | 8.25 | 8.75 | 10.1 | 9.2 | 8.0 | 6.55 | 6.25 | 6.15 | 6.1 | 6.3 | 6.3 |
| 29 | 7.25 | ..... | 8.95 | 10.35 | 9.1 | 8.0 | 6.55 | 6.15 | 6.15 | 6.1 | 6.4 | 6.4 |
| 30 | 7.05 | ..... | 8.75 | 10.45 | 9.3 | 8.0 | 6.5 | 6.25 | 6.15 | 6.1 | 6.5 | 6.45 |
| 31 | 6.75 | ..... | 8.65 | ..... | 9.35 | ..... | 6.45 | 6.2 | 6.15 | 6.1 | ..... | 6.4 |

*Station rating table for Stanislaus River at Knights Ferry, Cal., from January 1, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 6.00 | 60 | 7.30 | 630 | 8.60 | 1,840 | 9.90 | 3,550 |
| 6.10 | 70 | 7.40 | 710 | 8.70 | 1,960 | 10.00 | 3,700 |
| 6.20 | 80 | 7.50 | 800 | 8.80 | 2,080 | 10.20 | 4,040 |
| 6.30 | 95 | 7.60 | 890 | 8.90 | 2,200 | 10.40 | 4,400 |
| 6.40 | 125 | 7.70 | 980 | 9.00 | 2,320 | 10.60 | 4,800 |
| 6.50 | 160 | 7.80 | 1,070 | 9.10 | 2,440 | 10.80 | 5,230 |
| 6.60 | 200 | 7.90 | 1,160 | 9.20 | 2,560 | 11.00 | 5,730 |
| 6.70 | 245 | 8.00 | 1,250 | 9.30 | 2,680 | 11.20 | 6,330 |
| 6.80 | 295 | 8.10 | 1,340 | 9.40 | 2,800 | 11.40 | 6,990 |
| 6.90 | 350 | 8.20 | 1,440 | 9.50 | 2,950 | 11.60 | 7,700 |
| 7.00 | 410 | 8.30 | 1,540 | 9.60 | 3,100 | | |
| 7.10 | 480 | 8.40 | 1,640 | 9.70 | 3,250 | | |
| 7.20 | 550 | 8.50 | 1,740 | 9.80 | 3,400 | | |

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*Estimated monthly discharge of Stanislaus River at Knights Ferry, Cal., for 1905.*

[Drainage area, 935 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 1,015 | 294 | 642 | 39,480 | 0.687 | 0.792 |
| February | 4,002 | 731 | 1,326 | 73,640 | 1.42 | 1.48 |
| March | 7,394 | 1,533 | 2,395 | 147,300 | 2.56 | 2.95 |
| April | 4,625 | 1,905 | 2,774 | 165,100 | 2.97 | 3.31 |
| May | 6,445 | 2,124 | 3,247 | 99,650 | 3.47 | 4.00 |
| June | 3,296 | 1,351 | 2,392 | 142,300 | 2.56 | 2.86 |
| July | 1,309 | 225 | 613 | 37,690 | .656 | .756 |
| August | 211 | 97 | 150 | 9,223 | .160 | .184 |
| September | 137 | 90 | 103 | 6,129 | .110 | .123 |
| October | 138 | 85 | 97 | 5,964 | .104 | .120 |
| November | 189 | 77 | 91 | 5,415 | .097 | .108 |
| December | 185 | 96 | 131 | 8,055 | .140 | 1.61 |
| The year | 7,394 | 77 | 1,163 | 739,900 | 1.24 | 18.29 |

NOTE.—The discharge of Stanislaus Water Company's ditch and Schell ditch is included above. Mean daily flow of Schell ditch is estimated at 7 second-feet.

### STANISLAUS WATER COMPANY'S DITCH AT KNIGHTS FERRY, CAL.

This station was established June 11, 1904, by S. G. Bennett. The station is located below the point where Schell ditch diverts its water, about 1 mile below the Stanislaus Milling and Power Company's power house and 200 feet below the place where it passes under Schell ditch flume. The water diverted by this ditch is used for irrigation in the vicinity of Oakdale, Cal.

A meter measurement on Schell ditch 200 feet below its intake gave a discharge of about 7 second-feet, which is said to be its usual constant flow. In computing the estimated monthly discharge of Stanislaus River a mean daily discharge of 7 second-feet has been used as the capacity of Schell ditch.

The gage is fastened to the upstream side of a small bridge. During 1905 the gage was read once each day by E. J. Coop.

A description of this station, with gage height and discharge data, is contained in Water-Supply Paper No. 134, United States Geological Survey.

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*Discharge measurements of Stanislaus Water Company's ditch at Knights Ferry, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 14 | F. R. S. Buttemer | 13.2 | 22 | 2.14 | 2.58 | 47 |
| May 23 | R. S. Hawley | 8.7 | 27 | 4.24 | 3.65 | 114 |
| June 16 | do | 8.5 | 24 | 4.00 | 3.45 | 96 |
| July 20 | do | 9 | 21 | 3.67 | 3.00 | 77 |
| September 12 | C. H. Lee | 11 | 6.1 | .85 | 1.12 | 5.2 |
| September 12 | do | 8.7 | 5.5 | 1.58 | 1.50 | 8.7 |
| September 12 | do | 9.4 | 13.1 | 2.52 | 2.18 | 33 |
| September 12 | do | 9.4 | 12.6 | 2.38 | 2.08 | 30 |
| October 17 | R. S. Hawley | 7.5 | 2.1 | .38 | .80 | .8 |

*Daily gage height, in feet, of Stanislaus Water Company's canal at Knights Ferry, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.6 | 2.3 | 2.3 | 3.55 | 3.7 | 3.7 | 3.4 | 3.1 | 1.95 | 2.8 | 0.0 | 2.1 |
| 2 | 2.4 | 2.4 | 2.6 | 3.7 | 3.6 | 3.6 | 3.45 | 3.0 | 2.0 | 2.65 | 1.5 | 2.15 |
| 3 | 2.5 | 2.05 | .0 | 3.5 | 3.5 | 3.6 | 3.35 | 3.05 | 2.1 | 2.4 | 1.8 | 2.2 |
| 4 | 2.5 | 1.9 | .0 | 3.65 | 3.5 | 3.7 | 3.45 | 3.05 | 2.05 | 2.3 | 1.5 | 1.95 |
| 5 | 2.5 | .0 | .0 | 3.55 | 3.55 | 3.6 | 3.35 | 3.1 | 3.45 | 2.2 | 1.5 | 2.2 |
| 6 | 2.3 | 2.1 | 2.3 | 3.65 | 3.6 | 3.6 | 3.4 | 3.1 | 3.3 | 2.1 | 1.2 | 2.1 |
| 7 | 2.5 | .0 | 2.5 | 3.7 | 3.5 | 2.55 | 3.3 | 3.1 | 2.0 | 2.15 | .0 | 2.0 |
| 8 | 2.5 | .0 | 2.25 | 3.65 | 3.3 | 3.45 | 3.4 | 3.05 | 2.0 | 2.2 | .0 | 2.05 |
| 9 | 2.45 | .0 | 2.55 | 3.6 | 3.2 | 3.6 | 3.4 | 3.0 | 2.1 | 2.05 | .0 | 2.1 |
| 10 | 2.45 | .0 | 2.5 | 3.6 | 3.3 | 3.7 | 3.45 | 2.95 | 2.2 | 1.70 | .0 | 2.1 |
| 11 | 2.25 | .0 | 3.4 | 3.55 | 3.4 | 3.65 | 3.3 | 2.95 | 2.15 | 1.75 | .0 | 1.8 |
| 12 | 2.45 | 1.45 | 3.0 | 3.6 | 3.45 | 3.65 | 3.3 | 2.95 | 2.0 | 1.85 | .0 | 1.95 |
| 13 | 2.05 | .0 | 2.6 | 3.5 | 3.4 | 3.6 | 3.3 | 3.1 | 2.1 | 1.4 | .0 | 2.0 |
| 14 | 2.0 | 1.8 | 2.45 | 3.65 | 3.45 | 3.6 | 3.25 | 2.8 | 1.6 | 1.2 | .0 | 1.85 |
| 15 | 2.2 | 1.7 | 2.45 | 3.65 | 3.7 | 3.5 | 3.15 | 2.85 | 1.6 | 1.0 | .0 | 1.65 |
| 16 | 2.15 | 1.9 | 2.6 | 3.7 | 3.7 | 3.5 | 3.35 | 2.9 | 1.5 | 1.4 | .0 | 1.8 |
| 17 | 2.35 | 2.3 | 2.6 | 3.65 | 3.55 | 3.5 | 3.1 | 2.7 | 1.4 | 1.3 | .0 | 2.2 |
| 18 | 2.1 | 2.2 | 2.5 | 3.55 | 3.6 | 3.5 | 3.1 | 2.5 | 1.4 | 1.2 | .0 | 2.1 |
| 19 | 2.1 | 2.4 | 2.45 | 3.6 | 3.7 | 3.5 | 3.0 | 2.45 | 1.1 | 1.3 | .0 | 1.95 |
| 20 | 2.3 | 2.0 | 2.8 | 3.55 | 3.65 | 3.45 | 3.2 | 2.3 | 1.35 | 1.4 | .0 | 2.0 |
| 21 | 2.05 | 2.4 | 2.6 | 3.6 | 3.7 | 3.55 | 3.1 | 2.3 | 1.5 | 1.5 | .0 | 2.0 |
| 22 | 2.2 | 2.3 | 2.8 | 3.6 | 3.65 | 3.45 | 3.0 | 2.05 | 1.6 | 1.55 | .0 | 2.05 |
| 23 | 2.1 | 2.0 | 2.9 | 3.5 | 3.65 | 3.45 | 3.0 | 2.1 | 1.3 | 1.8 | .0 | 1.95 |
| 24 | 2.1 | 2.0 | 3.0 | 3.6 | 3.6 | 3.45 | .0 | 2.0 | 1.7 | 1.4 | .0 | 1.25 |
| 25 | 2.15 | 2.0 | 3.15 | 3.65 | 3.65 | 3.4 | 2.95 | 2.05 | 1.5 | 1.2 | .0 | 1.4 |
| 26 | 2.1 | .0 | 3.2 | 3.7 | 3.65 | 3.35 | 3.0 | 1.9 | 1.65 | 1.3 | .0 | .9 |
| 27 | 2.2 | 2.25 | 3.3 | 3.7 | 3.6 | 3.35 | 3.1 | 1.85 | 1.65 | 1.6 | 1.7 | 2.2 |
| 28 | 2.2 | 2.35 | 3.35 | 3.7 | 3.6 | 3.35 | 3.0 | 1.7 | 1.7 | 1.5 | 1.95 | 2.3 |
| 29 | 2.3 | ..... | 3.4 | 3.7 | 3.6 | 3.4 | 2.95 | 2.15 | 2.2 | 1.45 | 2.0 | 2.2 |
| 30 | 1.65 | ..... | 3.6 | 3.7 | 3.6 | 3.45 | 3.1 | 1.7 | 2.25 | 1.45 | 1.95 | 2.3 |
| 31 | 1.8 | ..... | 3.65 | ..... | 3.65 | ..... | 3.05 | 1.5 | ..... | 1.4 | ..... | 2.2 |

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*Station rating table for Stanislaus Water Company's ditch near Knights Ferry, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.00 | 2.5 | 1.70 | 14 | 2.40 | 40 | 3.10 | 79 |
| 1.10 | 3.5 | 1.80 | 17 | 2.50 | 45 | 3.20 | 85 |
| 1.20 | 5 | 1.90 | 20 | 2.60 | 50 | 3.30 | 91 |
| 1.30 | 6.5 | 2.00 | 24 | 2.70 | 55 | 3.40 | 97 |
| 1.40 | 8 | 2.10 | 28 | 2.80 | 61 | 3.50 | 104 |
| 1.50 | 10 | 2.20 | 32 | 2.90 | 67 | 3.60 | 111 |
| 1.60 | 12 | 2.30 | 36 | 3.00 | 73 | 3.70 | 118 |

NOTE.—The above table is based on 9 discharge measurements made during 1905. It is well defined between gage heights 1 foot and 3.7 feet. Monthly estimates are included with those of Stanislaus River, page —.

### MISCELLANEOUS MEASUREMENTS IN STANISLAUS RIVER DRAINAGE BASIN.

*Stanislaus River at Parrotts Ferry, Cal.*—A measurement was made on this stream from the downstream side of the wagon bridge at Parrotts Ferry on September 12, 1905, by H. A. Campbell.

Width, 35 feet; area, 138 square feet; mean velocity, 0.66 foot per second; discharge, 91 second-feet.

*South Fork of Stanislaus.*—A measurement was made on this stream on September 25, 1905, at trail crossing to Yancey's ranch about 14 miles above its junction with the main river and about 3 miles north of Confidence, Cal. Measurement made by H. A. Campbell.

Width, 5 feet; area, 2.4 square feet; mean velocity, 0.40 foot per second; discharge, 0.96 second-feet.

*Middle Fork of Stanislaus.*—A measurement was made on this stream on September 26, 1905, at the bridge on the trail to McCormicks, about 5 miles above its junction with the main river. Measurement made by H. A. Campbell.

Width, 21 feet; area, 350 square feet; mean velocity, 0.24 foot per second; discharge, 84 second-feet.

*Griswald Creek.*—This stream enters Stanislaus River about 2 miles above the mouth of the Middle Fork. A measurement was made on September 26, 1905, at trail crossing, about 5 miles above the mouth, by H. A. Campbell.

Width, 6 feet; area, 5.4 square feet; mean velocity, 0.37 foot; discharge, 2.0 second-feet.

*Beaver Creek.*—This stream enters Stanislaus River from the east about 5 miles above the mouth of the Middle Fork. A measurement was made on September 26, 1905, at the trail crossing to the Calaveras big trees and about 5 miles above its junction with North Fork of Stanislaus River. Measurement made by H. A. Campbell.

Width, 2.5 feet; area, 2.8 square feet; mean velocity, 1.64 feet per second; discharge, 4.6 second-feet.

*North Fork of Stanislaus River at Squaw Hollow, Cal.*—A measurement was made about 75 yards upstream from trail bridge at Squaw Hollow on September 27, 1905, by H. A. Campbell.

Width, 29 feet; area, 48 square feet; mean velocity, 1.60 feet per second; discharge, 77 second-feet.

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## MOKELUMNE RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Mokelumne River drains an area of 657 square miles of the western slope of the Sierra Nevada. It has numerous tributaries, the North, South, and Middle forks being the most important. This stream heads well back in the main crest of the Sierra Nevada at an elevation of 8,000 feet.

The formation is of granite with good soil covering and heavy timber growth on the middle and higher elevations. On the lower elevations the slopes are less rugged and the soil covering is of brush and scattering oak timber with large areas of cultivated land and pasture. There are numerous small glacial lakes and moraines in the upper reaches of this basin. The precipitation varies from 25 inches on the lower to 50 inches on the higher elevations, where it falls in the form of snow, which melts in the early spring. The greatest discharge usually occurs in April, May, and June. There is some artificial storage in this basin, but not enough to have much effect on the discharge.

Several diversions are made for mining and power purposes within the drainage basin, and this water is returned to the river above the gaging station, which is located at Clement, a few miles above Lodi, Cal.

### MOKELUMNE RIVER NEAR CLEMENTS, CAL.

This station was established October 28, 1904, by O. W. Peterson. It is located at the highway bridge, 1 mile north of Clements.

The channel is straight for 150 feet above and 500 feet below the gaging station. The right bank is high and not subject to overflow. The left bank is subject to overflow when the gage reads above 15 feet. The bed of the stream is composed of gravel and is subject to slight changes.

Discharge measurements are made from the downstream side of the bridge. The initial point is on the end of the bridge near the right bank.

The gage is in two sections. The low-water section is an inclined rod nailed to posts driven in the ground, and the high-water section is a vertical rod nailed to a pile and near the inclined rod. Both are on the right bank. During 1905 the gage was read by Allen Gaskill. The bench mark is the head of a bolt driven in a pile, to which the upper section of the gage is fastened; elevation, 9.60 feet above the datum of the gage.

A description of this station, with gage height and discharge data, is contained in Water-Supply Paper No. 134, United States Geological Survey.

*Discharge measurements of Mokelumne River near Clements, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 23 | F. R. S. Buttemer | 132 | 293 | 2.69 | 5.15 | 788 |
| January 24 | do | 128 | 258 | 2.40 | 4.85 | 620 |
| January 24 | do | 128 | 250 | 2.38 | 4.79 | 596 |
| January 30 | do | 121 | 191 | 2.01 | 4.28 | 384 |
| February 9 | do | 126 | 259 | 2.39 | 4.87 | 620 |
| February 15 | do | 122 | 193 | 2.27 | 4.31 | 438 |
| February 20 | do | 210 | 562 | 2.54 | 6.14 | 1,425 |
| May 18 | W. B. Clapp | 248 | 1,238 | 3.06 | 9.00 | 3,788 |
| June 29 | O. W. Peterson | 130 | 237 | 2.36 | 4.64 | 559 |
| July 28 | Peterson and Lee | 60 | 80 | 1.56 | 3.14 | 125 |
| September 5 | C. H. Lee | 58 | 79 | 1.27 | 3.13 | 100 |
| November 29 | do | 55 | 66 | .86 | 2.90 | 57 |

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*Daily gage height, in feet, of Mokelumne River near Clements, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.0 | 4.85 | 5.4 | 6.05 | 7.5 | 7.65 | 4.3 | 3.2 | 3.3 | 3.4 | 3.25 | 3.25 |
| 2 | 4.55 | 7.55 | 5.45 | 6.2 | 7.0 | 7.45 | 4.3 | 3.3 | 3.3 | 3.25 | 3.2 | 3.1 |
| 3 | 4.5 | 5.8 | 5.5 | 6.3 | 6.9 | 7.15 | 4.1 | 3.3 | 3.25 | 3.3 | 3.25 | 3.1 |
| 4 | 4.4 | 5.35 | 5.65 | 6.45 | 6.65 | 6.9 | 4.0 | 3.3 | 3.3 | 3.25 | 3.1 | 3.0 |
| 5 | 4.15 | 6.55 | 5.6 | 6.7 | 6.5 | 6.6 | 3.85 | 3.2 | 3.3 | 3.3 | 3.1 | 2.95 |
| 6 | 4.3 | 5.7 | 5.7 | 6.8 | 6.4 | 6.8 | 3.85 | 3.25 | 3.3 | 3.3 | 3.1 | 2.95 |
| 7 | 4.1 | 5.3 | 5.5 | 6.95 | 6.6 | 7.1 | 3.8 | 3.15 | 3.3 | 3.45 | 3.1 | 3.1 |
| 8 | 4.1 | 5.0 | 5.6 | 7.05 | 6.9 | 7.05 | 4.05 | 3.3 | 3.35 | 3.4 | 2.95 | 3.1 |
| 9 | 4.3 | 4.9 | 5.45 | 6.85 | 6.55 | 7.0 | 3.65 | 3.25 | 3.3 | 3.25 | 3.0 | 3.05 |
| 10 | 4.3 | 4.65 | 5.45 | 7.0 | 6.4 | 7.15 | 3.6 | 3.3 | 3.3 | 3.35 | 2.95 | 3.05 |
| 11 | 4.1 | 4.65 | 5.5 | 6.6 | 6.3 | 7.55 | 3.7 | 3.2 | 3.2 | 3.3 | 2.95 | 3.0 |
| 12 | 4.1 | 4.55 | 5.45 | 6.25 | 6.3 | 7.75 | 3.6 | 3.3 | 3.3 | 3.35 | 2.95 | 3.1 |
| 13 | 4.15 | 4.5 | 6.1 | 6.25 | 6.25 | 7.75 | 3.65 | 3.2 | 3.3 | 3.35 | 2.9 | 3.05 |
| 14 | 4.15 | 4.55 | 6.15 | 6.45 | 6.2 | 7.1 | 3.45 | 2.9 | 3.35 | 3.15 | 2.95 | 3.1 |
| 15 | 4.2 | 4.35 | 5.55 | 6.6 | 7.4 | 6.95 | 3.45 | 3.35 | 3.35 | 3.15 | 2.85 | 3.05 |
| 16 | 4.7 | 4.4 | 5.6 | 6.75 | 8.25 | 6.85 | 3.35 | 3.3 | 3.3 | 3.25 | 2.85 | 3.05 |
| 17 | 4.3 | 4.95 | 6.2 | 6.35 | 10.55 | 6.65 | 3.3 | 3.3 | 3.3 | 3.25 | 2.8 | 3.1 |
| 18 | 4.25 | 4.9 | 6.55 | 6.9 | 9.0 | 6.5 | 3.3 | 3.35 | 3.35 | 3.05 | 2.8 | 3.15 |
| 19 | 4.35 | 4.85 | 7.05 | 6.8 | 8.85 | 6.25 | 3.3 | 3.4 | 3.35 | 3.2 | 2.85 | 3.15 |
| 20 | 4.4 | 5.8 | 7.3 | 6.35 | 8.8 | 6.15 | 3.3 | 3.25 | 3.35 | 3.1 | 2.9 | 3.2 |
| 21 | 4.45 | 5.5 | 6.85 | 6.05 | 8.85 | 6.0 | 3.3 | 3.25 | 3.35 | 3.05 | 3.05 | 3.3 |
| 22 | 4.45 | 5.25 | 6.65 | 6.05 | 8.25 | 5.75 | 3.3 | 3.25 | 3.4 | 3.0 | 2.85 | 3.35 |
| 23 | 5.0 | 5.15 | 6.3 | 6.25 | 7.9 | 5.45 | 3.3 | 3.25 | 3.35 | 2.9 | 2.9 | 3.3 |
| 24 | 4.85 | 5.1 | 6.55 | 6.7 | 8.65 | 5.35 | 3.3 | 3.25 | 3.4 | 2.95 | 2.95 | 3.2 |
| 25 | 4.6 | 5.25 | 6.5 | 7.25 | 8.6 | 4.9 | 3.3 | 3.3 | 3.3 | 3.1 | 2.85 | 3.0 |
| 26 | 4.55 | 5.45 | 6.3 | 7.6 | 8.95 | 5.1 | 3.25 | 3.35 | 3.35 | 3.0 | 2.85 | 2.95 |
| 27 | 4.45 | 5.55 | 6.9 | 8.3 | 7.35 | 4.9 | 3.2 | 3.35 | 3.35 | 3.2 | 3.2 | 3.05 |
| 28 | 4.2 | 5.35 | 6.45 | 8.3 | 7.1 | 4.75 | 3.2 | 3.3 | 3.35 | 3.15 | 3.25 | 3.1 |
| 29 | 4.25 | ..... | 6.85 | 8.4 | 7.45 | 4.65 | 3.15 | 3.25 | 3.35 | 3.0 | 3.3 | 3.1 |
| 30 | 4.3 | ..... | 6.4 | 8.15 | 7.45 | 4.4 | 3.15 | 3.3 | 3.45 | 3.05 | 3.15 | 3.1 |
| 31 | 4.35 | ..... | 6.2 | ..... | 7.6 | ..... | 3.2 | 3.35 | ..... | 3.15 | ..... | 3.15 |

*Station rating table for Mokelumne River near Clements, Cal., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.00 | 78 | 4.30 | 391 | 5.60 | 1,059 | 6.90 | 2,000 |
| 3.10 | 96 | 4.40 | 427 | 5.70 | 1,124 | 7.00 | 2,080 |
| 3.20 | 115 | 4.50 | 465 | 5.80 | 1,191 | 7.20 | 2,240 |
| 3.30 | 134 | 4.60 | 506 | 5.90 | 1,260 | 7.40 | 2,400 |
| 3.40 | 154 | 4.70 | 550 | 6.00 | 1,330 | 7.60 | 2,560 |
| 3.50 | 174 | 4.80 | 597 | 6.10 | 1,400 | 7.80 | 2,730 |
| 3.60 | 195 | 4.90 | 647 | 6.20 | 1,475 | 8.00 | 2,900 |
| 3.70 | 218 | 5.00 | 700 | 6.30 | 1,550 | 8.20 | 3,070 |
| 3.80 | 242 | 5.10 | 755 | 6.40 | 1,625 | 8.40 | 3,250 |
| 3.90 | 268 | 5.20 | 812 | 6.50 | 1,700 | 8.60 | 3,430 |
| 4.00 | 295 | 5.30 | 871 | 6.60 | 1,775 | 8.80 | 3,610 |
| 4.10 | 325 | 5.40 | 932 | 6.70 | 1,850 | 9.00 | 3,800 |
| 4.20 | 357 | 5.50 | 995 | 6.80 | 1,925 | | |

NOTE.—The above table is based on 12 discharge measurements made during 1905. It is well defined between gage heights 2.9 feet and 6.2 feet. The table has been extended beyond these limits, being based on 1 measurement at 9 feet gage height.

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*Estimated monthly discharge of Mokelumne River near Clements, Calif., for 1905.*

[Drainage area, 642 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Sec.-feet per sq. mile. | Depth in inches. |
| January | 700 | 325 | 428 | 26,320 | .667 | .769 |
| February | 2,520 | 409 | 853 | 47,370 | 1.33 | 1.38 |
| March | 2,320 | 932 | 1,410 | 86,700 | 2.20 | 2.54 |
| April | 3,250 | 1,365 | 1,959 | 116,600 | 3.05 | 3.40 |
| May | 5,260 | 1,475 | 2,547 | 156,600 | 3.97 | 4.58 |
| June | 2,688 | 427 | 1,665 | 99,070 | 2.59 | 2.89 |
| July | 391 | 106 | 188 | 11,560 | .293 | .338 |
| August | 154 | 60 | 128 | 7,870 | .199 | .229 |
| September | 164 | 115 | 139 | 8,271 | .217 | .242 |
| October | 164 | 60 | 114 | 7,010 | .178 | .205 |
| November | 134 | 43 | 794 | 4,725 | .124 | .138 |
| December | 144 | 69 | 970 | 5,964 | .151 | .174 |
| The year | 5,260 | 43 | 801 | 578,100 | 1.25 | 16.88 |

## NORTHERN PACIFIC OCEAN DRAINAGE BASIN.

### RUSSIAN RIVER DRAINAGE BASIN.

#### MISCELLANEOUS MEASUREMENTS.

The following is a list of miscellaneous discharge measurements made in Russian River drainage basin during 1905:

*Russian River at Calpella, Cal.*—A measurement of this stream was made on September 21, 1905, one-fourth mile east of Calpella and about 3 miles above mouth of East Fork of Russian River by R. S. Hawley.

Width, 6 feet; area, 1.6 square feet; mean velocity, 0.75 foot per second; discharge, 1.2 second-feet.

*East Fork of Russian River near Ukiah, Cal.*—A measurement of this stream was made September 21, 1905, one-fourth mile above its junction with Russian River by R. S. Hawley.

Width, 10 feet; area, 4.6 square feet; mean velocity, 0.48 foot per second; discharge, 2.2 second-feet.

*Russian River at Preston, Cal.*—A measurement of this stream was made September 22, 1905, 1 mile above Preston, Cal., by R. S. Hawley.

Width, 23 feet; area, 9.8 square feet; mean velocity, 1.05 feet per second; discharge, 10.3 second-feet.

### EEL RIVER DRAINAGE BASIN.

#### MISCELLANEOUS MEASUREMENTS.

The following is a list of miscellaneous discharge measurements made in Eel River drainage basin during 1905:

*South Eel River at Hearst, Cal.*—This stream is tributary to the Eel River from the south. A measurement was made 600 feet below the Hearst bridge on September 19, 1905, by R. S. Hawley.

Width, 20 feet; area, 7.6 square feet; mean velocity, 1.25 feet per second; discharge, 9.5 second-feet.

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*Middle Eel River at Covelo, Cal.*—A measurement of this stream was made September 19, 1905, at the road crossing between Willets and Covelo about 7 miles above its junction with South Eel by R. S. Hawley.

Width, 34 feet; area, 12.2 square feet; mean velocity, 0.57 foot per second; discharge, 7.0 second-feet.

*Middle Eel River at Laytonville, Cal.*—A measurement of this stream was made September 20, 1905, 50 feet above its junction with South Eel River by R. S. Hawley.

Width, 18 feet; area, 22 square feet; mean velocity, 0.36 foot per second; discharge, 8.0 second-feet.

*Eel River at Laytonville, Cal.*—A measurement of this stream was made September 20, 1905, 50 feet below the junction of Middle and South Eel rivers by R. S. Hawley.

Width, 20 feet; area, 16 square feet; mean velocity, 1.69 feet per second; discharge, 27 second-feet.

*South Eel River at Laytonville, Cal.*—From the difference of the measurement made below the junction of the Middle and South Eel and that made on Middle Eel above on September 20, 1905, the discharge of South Eel at the junction is 19.2 second-feet.

## KLAMATH RIVER DRAINAGE BASIN.

### LINK RIVER AT KLAMATH FALLS, OREG.[a]

This station was established May 15, 1904, by J. H. Lewis. It is located at the county bridge at Klamath Falls, Oreg., 1½ miles below the outlet of Klamath Lake.

The channel is straight for 400 feet above and below the station. The current is swift; the fall in the 1½ miles between the lake and the gaging station is about 70 feet. The right bank is low and wooded, but not liable to overflow. The left bank is high and rocky. The bed of the stream is composed of gravel, free from vegetation, and subject to some change. There is but one channel at all stages. One irrigation ditch takes water from the river on the left bank about three-fourths mile above the station. Driftwood from a sawmill above the station collects around the bridge piers and interferes materially with the accuracy of measurements. A short distance below the gaging station the river discharges into a lake of considerable size. At flood stages the velocity is checked by water backing up from the lake below, which has a tendency to give decreased velocities with high gage readings. Gage heights may be affected by wind piling up the water of the upper and lower lakes.

Discharge measurements are made from the upstream side of the bridge. The initial point for soundings is the first vertical rod supporting the floor beam at the left end of the bridge, upstream side.

A staff gage is fastened vertically to the plank bracing between steel caissons near the left bank. During 1905 the gage was read once each day by G. H. Woodbury. Bench marks were established as follows: (1) A 30-penny nail driven into the floor beam over the gage; elevation, 12.50 feet. (2) The center of a cross cut in the first sandstone above the ground in the southwest corner of the foundation of the Linkville Hotel; elevation, 15.88 feet. Elevations refer to the datum of the gage.

Gage heights and discharge measurements taken at this station in 1904 are contained in Water-Supply Paper No. 134, United States Geological Survey.

[a] This station was known as Klamath River at Klamath Falls, Oreg., in report for 1904.

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*Discharge measurements of Link River at Klamath Falls, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 4 | C. T. Darley | 282 | 1,571 | 1.82 | 4.05 | 2,862 |
| January 17 | do | 282 | 1,570 | 1.76 | 4.10 | 2,768 |
| January 17 | do | 282 | 1,571 | 1.83 | 4.10 | 2,872 |
| January 17 | do | 282 | 1,571 | 1.67 | 4.10 | 2,627 |
| February 1 | do | 287 | 1,660 | 2.01 | 4.30 | 3,338 |
| February 13 | do | 288 | 1,683 | 1.78 | 4.50 | 2,994 |
| February 17 | do | 288 | 1,648 | 1.70 | 4.40 | 2,802 |
| March 2 | do | 288 | 1,642 | 1.82 | 4.40 | 2,984 |
| April 12 | do | 290 | 1,733 | 2.10 | 4.49 | 3,645 |
| June 5 | do | 279 | 1,494 | 1.56 | 3.88 | 2,324 |
| June 20 | do | 277 | 1,410 | 1.28 | 3.59 | 1,800 |
| June 28 | do | 283 | 1,354 | 1.12 | 3.40 | 1,517 |
| July 11 | do | 297 | 1,280 | 1.15 | 3.14 | 1,466 |
| July 18 | do | 272 | 1,234 | .86 | 2.97 | 1,063 |
| July 28 | do | 270 | 1,178 | .89 | 2.80 | 1,049 |
| August 7 | do | 267 | 1,162 | .90 | 2.63 | 1,041 |
| August 14 | do | 267 | 1,146 | .93 | 2.59 | 1,066 |
| August 16 | W. B. Clapp and C. T. Darley | 267 | 1,187 | .93 | 2.60 | 1,104 |
| September 7 | C. T. Darley | 267 | 1,141 | .90 | 2.58 | 1,032 |
| September 16 | do | 268 | 1,155 | .93 | 2.58 | 1,073 |
| November 2 | do | 272 | 1,254 | 1.02 | 2.90 | 1,283 |

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*Daily gage height, in feet, of Link River at Klamath Falls, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.1 | 4.2 | 4.4 | 4.5 | 4.2 | 3.95 | 3.45 | 2.79 | 2.6 | 2.7 | 2.81 | 3.25 |
| 2 | 4.1 | 4.4 | 4.4 | 4.5 | 4.2 | 3.85 | 3.45 | 2.75 | 2.6 | 2.65 | 2.8 | 3.3 |
| 3 | 4.1 | 4.4 | 4.4 | 4.5 | 4.2 | 3.85 | 3.3 | 2.7 | 2.58 | 2.7 | 2.81 | 3.29 |
| 4 | 4.1 | 4.4 | 4.4 | 4.5 | 4.2 | 3.9 | a3.3 | 2.67 | 2.6 | 2.7 | 2.84 | 3.2 |
| 5 | 4.1 | 4.5 | 4.4 | 4.5 | 4.2 | 3.88 | 3.25 | 2.67 | 2.58 | 2.9 | 2.82 | 3.2 |
| 6 | 4.1 | 4.5 | 4.4 | 4.5 | 4.2 | 3.88 | 3.3 | 2.67 | 2.6 | 2.9 | 2.88 | 3.2 |
| 7 | 4.1 | 4.4 | 4.4 | 4.5 | 4.2 | 3.81 | 3.2 | 2.5 | 2.58 | 2.95 | 2.86 | 3.21 |
| 8 | 4.1 | 4.4 | 4.4 | 4.5 | 4.2 | 3.88 | 3.2 | 2.63 | 2.58 | 2.7 | 2.99 | 3.23 |
| 9 | 4.1 | 4.4 | 4.4 | 4.5 | 4.2 | 3.85 | a3.25 | 2.6 | 2.58 | 2.9 | 2.99 | 3.24 |
| 10 | 4.1 | 4.5 | 4.4 | 4.5 | 4.2 | 3.8 | 3.25 | 2.6 | 2.62 | 2.8 | 2.98 | 3.28 |
| 11 | 4.1 | 4.5 | 4.4 | 4.5 | 4.2 | 3.8 | a3.25 | 2.59 | 2.63 | 2.75 | 2.99 | 3.25 |
| 12 | 4.1 | 4.5 | 4.4 | 4.5 | 4.2 | 3.78 | a3.2 | 2.6 | 2.58 | 2.8 | 2.9 | 3.26 |
| 13 | 4.1 | 4.5 | 4.4 | 4.5 | 4.2 | 3.75 | 3.2 | 2.6 | 2.58 | 2.8 | 2.95 | 3.27 |
| 14 | 4.1 | 4.5 | 4.4 | 4.5 | 4.2 | 3.7 | 3.1 | 2.59 | 2.6 | 2.8 | 2.95 | 3.34 |
| 15 | 4.1 | 4.5 | 4.4 | 4.5 | 4.1 | 3.6 | 3.05 | 2.6 | 2.6 | 2.7 | 2.95 | 3.34 |
| 16 | 4.1 | 4.5 | 4.4 | 4.5 | 4.1 | 3.7 | a3.0 | 2.6 | 2.55 | 2.8 | 2.9 | 3.26 |
| 17 | 4.1 | 4.4 | 4.4 | 4.5 | 4.1 | 3.62 | 2.9 | 2.60 | 2.5 | 2.8 | 2.9 | 3.33 |
| 18 | 4.1 | 4.4 | 4.4 | 4.45 | 4.05 | a3.61 | 2.9 | 2.63 | 2.55 | 2.8 | 2.9 | 3.32 |
| 19 | 4.1 | 4.4 | 4.4 | 4.4 | 4.05 | 3.6 | 3.0 | 2.6 | 2.6 | 2.8 | 3.2 | 3.32 |
| 20 | 4.1 | 4.4 | 4.4 | 4.4 | 4.05 | 3.59 | 2.9 | 2.6 | 2.6 | 2.85 | 3.1 | 3.26 |
| 21 | 4.1 | 4.4 | 4.4 | 4.35 | 4.0 | a3.55 | 2.9 | 2.6 | 2.6 | 2.85 | 3.3 | 3.27 |
| 22 | 4.1 | 4.4 | 4.4 | 4.35 | 4.0 | 3.5 | 2.95 | 2.6 | 2.58 | 2.79 | 3.2 | 3.33 |
| 23 | 4.1 | 4.4 | 4.4 | 4.35 | 4.0 | 3.5 | 2.85 | 2.6 | 2.6 | 2.8 | 3.15 | 3.3 |
| 24 | 4.2 | 4.4 | 4.4 | 4.3 | 4.0 | 3.5 | 2.85 | 2.6 | 2.68 | 2.85 | 3.1 | 3.32 |
| 25 | 4.2 | 4.4 | 4.4 | 4.3 | 4.0 | 3.4 | a2.85 | 2.6 | 2.55 | 2.81 | 3.2 | 3.29 |
| 26 | 4.2 | 4.4 | 4.4 | 4.3 | 4.0 | 3.4 | a2.85 | 2.7 | 2.58 | 2.8 | 3.25 | 3.35 |
| 27 | 4.2 | 4.4 | 4.4 | 4.3 | 4.0 | 3.4 | a2.8 | 2.8 | 2.6 | 2.89 | 3.15 | 3.36 |
| 28 | 4.1 | 4.4 | 4.5 | 4.25 | 4.0 | 3.4 | a2.8 | 2.6 | 2.62 | 2.88 | 3.15 | 3.33 |
| 29 | 4.2 | ..... | 4.6 | 4.25 | 4.0 | 3.4 | 2.78 | 2.6 | 2.65 | 2.88 | 3.4 | 3.4 |
| 30 | 4.2 | ..... | 4.5 | 4.25 | 3.95 | 3.35 | 2.79 | 2.65 | 2.65 | 2.81 | 3.2 | 3.53 |
| 31 | 4.2 | ..... | 4.5 | ..... | 3.95 | ..... | 2.78 | 2.55 | ..... | 2.9 | ..... | 3.53 |

a Estimated.

*Station rating table for Link River at Klamath Falls, Oreg., from May 15, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.50 | 985 | 3.60 | 1,920 | 4.70 | 3,580 | 5.80 | 5,790 |
| 2.60 | 1,035 | 3.70 | 2,045 | 4.80 | 3,770 | 5.90 | 6,020 |
| 2.70 | 1,090 | 3.80 | 2,175 | 4.90 | 3,960 | 6.00 | 6,250 |
| 2.80 | 1,150 | 3.90 | 2,310 | 5.00 | 4,150 | 6.20 | 6,710 |
| 2.90 | 1,220 | 4.00 | 2,450 | 5.10 | 4,340 | 6.40 | 7,180 |
| 3.00 | 1,300 | 4.10 | 2,590 | 5.20 | 4,530 | 6.60 | 7,660 |
| 3.10 | 1,390 | 4.20 | 2,740 | 5.30 | 4,730 | 6.80 | 8,140 |
| 3.20 | 1,485 | 4.30 | 2,900 | 5.40 | 4,930 | 7.00 | 8,640 |
| 3.30 | 1,585 | 4.40 | 3,060 | 5.50 | 5,140 | 7.20 | 9,140 |
| 3.40 | 1,690 | 4.50 | 3,230 | 5.60 | 5,350 | | |
| 3.50 | 1,800 | 4.60 | 3,400 | 5.70 | 5,570 | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on twenty-eight discharge measurements made during 1904-5. It is not very well defined.

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*Estimated monthly discharge of Link River at Klamath Falls, Oreg., for 1904 and 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean | |
| **1904.** | | | | |
| May 15–31 | 9,015 | 8,140 | 8,640 | 291,300 |
| June | 8,140 | 5,245 | 6,740 | 401,100 |
| July | 5,140 | 3,060 | 4,123 | 253,500 |
| August | 2,980 | 1,860 | 2,336 | 143,600 |
| September | 1,800 | 1,535 | 1,662 | 98,900 |
| October | 1,745 | 1,585 | 1,686 | 103,700 |
| November | 1,982 | 1,745 | 1,837 | 109,300 |
| December | 2,520 | 1,860 | 2,185 | 134,400 |
| The period | | | | 1,536,000 |
| **1905.** | | | | |
| January | 2,740 | 2,590 | 2,624 | 161,300 |
| February | 3,230 | 2,740 | 3,103 | 172,300 |
| March | 3,400 | 3,060 | 3,087 | 189,800 |
| April | 3,230 | 2,820 | 3,106 | 184,800 |
| May | 2,740 | 2,380 | 2,597 | 159,700 |
| June | 2,380 | 1,638 | 2,004 | 119,200 |
| July | 1,745 | 1,138 | 1,363 | 83,810 |
| August | 1,144 | 985 | 1,051 | 64,620 |
| September | 1,062 | 985 | 1,033 | 61,290 |
| October | 1,260 | 1,062 | 1,159 | 71,260 |
| November | 1,690 | 1,150 | 1,330 | 79,140 |
| December | 1,860 | 1,485 | 1,587 | 100,800 |
| The year | 3,400 | 985 | 2,004 | 1,448,000 |

### KLAMATH RIVER AT KENO, OREG.

This station was established August 13, 1904, by T. H. Humphreys. It is located one-fourth mile below the county bridge at Keno, Oreg.

The channel is straight for one-fourth mile above and below the station. The current is sluggish at low and moderate at high stages. Both banks are low, clean, and liable to overflow. The bed of the stream is composed of bowlders. An up or down stream wind piles up the water near the gage on account of the low velocities.

Discharge measurements are made by means of a cable and car one-fourth mile downstream from the bridge. The initial point for soundings is at the cable support on the right bank.

A staff gage is fastened vertically to the downstream side of the second bent from the left end of the bridge. During 1905 the gage was read once each day by S. Padgett. Bench marks were established as follows: (1) The top of projecting cap of bridge bent to which the gage is nailed; elevation, 16.80 feet. (2) A 60-penny nail driven into the south gatepost on the west side of the road 58 feet from the south end of the bridge; elevation, 18.85 feet. Elevations refer to the datum of the gage.

Gage heights and discharge measurements taken at this station in 1904 are contained in Water-Supply Paper No. 134, United States Geological Survey.

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*Discharge measurements of Klamath River at Keno, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 10 | C. T. Darley | 407 | 3,800 | 0.68 | 13.00 | 2,590 |
| January 23 | do | 420 | 3,794 | .77 | 13.30 | 2,930 |
| January 30 | do | 420 | 3,804 | .76 | 13.20 | 2,875 |
| February 9 | do | 425 | 3,700 | .80 | 13.25 | 2,975 |
| February 18 | do | 428 | 3,838 | .83 | 13.30 | 3,192 |
| March 3 | do | 432 | 3,850 | .82 | 13.30 | 3,145 |
| March 31 | do | 425 | 3,828 | .83 | 13.32 | 3,159 |
| April 13 | do | 425 | 3,760 | .80 | 13.28 | 3,015 |
| May 17 | do | 427 | 3,687 | .73 | 13.03 | 2,676 |
| June 19 | do | 410 | 3,545 | .59 | 12.68 | 2,102 |
| July 14 | do | 407 | 3,348 | .43 | 12.20 | 1,445 |
| August 14 | do | 402 | 3,129 | .37 | 11.80 | 1,146 |
| August 31 | do | 404 | 3,221 | .29 | 11.75 | 924 |
| November 3 | do | 409 | 3,325 | .20 | 12.00 | 680 |
| December 3 | do | 410 | 3,390 | .25 | 12.28 | 851 |

*Daily gage height, in feet, of Klamath River at Keno, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12.9 | 13.2 | 13.3 | 13.4 | 13.2 | 13.0 | 12.5 | 11.9 | 11.8 | 11.9 | 12.1 | 12.3 |
| 2 | 12.9 | 13.2 | 13.3 | 13.4 | 13.2 | 13.0 | 12.4 | 11.9 | 11.8 | 11.9 | 12.1 | 12.3 |
| 3 | 13.0 | 13.3 | 13.3 | 13.4 | 13.2 | 13.0 | 12.4 | 11.9 | 11.8 | 11.9 | 12.1 | 12.3 |
| 4 | 13.0 | 13.3 | 13.3 | 13.4 | 13.2 | 13.0 | 12.4 | 11.9 | 11.8 | 11.9 | 12.1 | 12.3 |
| 5 | 13.0 | 13.3 | 13.3 | 13.4 | 13.2 | 13.0 | 12.4 | 11.9 | 11.8 | 11.9 | 12.1 | 12.3 |
| 6 | 13.0 | 13.3 | 13.3 | 13.4 | 13.2 | 12.9 | 12.3 | 11.8 | 11.8 | 11.9 | 12.1 | 12.3 |
| 7 | 13.0 | 13.3 | 13.3 | 13.4 | 13.2 | 12.9 | 12.3 | 11.8 | 11.8 | 11.9 | 12.1 | 12.3 |
| 8 | 13.1 | 13.3 | 13.3 | 13.4 | 13.1 | 12.9 | 12.2 | 11.8 | 11.8 | 11.9 | 12.1 | 12.4 |
| 9 | 13.1 | 13.3 | 13.3 | 13.4 | 13.1 | 12.9 | 12.2 | 11.8 | 11.8 | 11.9 | 12.1 | 12.4 |
| 10 | 13.1 | 13.3 | 13.3 | 13.4 | 13.1 | 12.9 | 12.2 | 11.8 | 11.8 | 11.9 | 12.1 | 12.4 |
| 11 | 13.1 | 13.3 | 13.3 | 13.4 | 13.1 | 12.9 | 12.2 | 11.8 | 11.8 | 11.9 | 12.1 | 12.4 |
| 12 | 13.1 | 13.3 | 13.3 | 13.3 | 13.1 | 12.8 | 12.2 | 11.8 | 11.8 | 11.9 | 12.1 | 12.4 |
| 13 | 13.1 | 13.3 | 13.2 | 13.3 | 13.1 | 12.8 | 12.2 | 11.8 | 11.8 | 11.9 | 12.1 | 12.4 |
| 14 | 13.1 | 13.3 | 13.2 | 13.3 | 13.1 | 12.8 | 12.2 | 11.8 | 11.8 | 11.9 | 12.1 | 12.4 |
| 15 | 13.1 | 13.3 | 13.2 | 13.3 | 13.1 | 12.7 | 12.2 | 11.8 | 11.8 | 11.9 | 12.1 | 12.4 |
| 16 | 13.1 | 13.3 | 13.2 | 13.3 | 13.1 | 12.7 | 12.2 | 11.8 | 11.8 | 11.9 | 12.2 | 12.4 |
| 17 | 13.1 | 13.3 | 13.2 | 13.3 | 13.0 | 12.7 | 12.2 | 11.8 | 11.8 | 12.0 | 12.2 | 12.4 |
| 18 | 13.1 | 13.3 | 13.2 | 13.3 | 13.0 | 12.7 | 12.2 | 11.8 | 11.8 | 12.0 | 12.2 | 12.4 |
| 19 | 13.1 | 13.3 | 13.2 | 13.2 | 13.0 | 12.6 | 12.1 | 11.8 | 11.8 | 12.0 | 12.2 | 12.4 |
| 20 | 13.1 | 13.3 | 13 2 | 13 2 | 13 0 | 12 6 | 12 1 | 11 8 | 11 8 | 12.0 | 12.2 | 12 4 |
| 21 | 13 1 | 13 3 | 13 2 | 13 2 | 13 0 | 12 6 | 12 1 | 11 8 | 11 8 | 12.0 | 12.3 | 12.4 |
| 22 | 13.1 | 13.3 | 13.2 | 13.2 | 13.0 | 12.5 | 12.1 | 11.8 | 11.8 | 12.0 | 12.3 | 12.4 |
| 23 | 13.3 | 13.3 | 13.2 | 13.2 | 13.0 | 12.5 | 12.1 | 11.8 | 11.8 | 12.0 | 12.3 | 12.4 |
| 24 | 13.1 | 13.3 | 13.2 | 13.2 | 13.0 | 12.5 | 12.1 | 11.8 | 11.8 | 12.0 | 12.3 | 12.4 |
| 25 | 13.1 | 13.3 | 13.3 | 13.2 | 13.0 | 12.5 | 12.0 | 11.8 | 11.8 | 12.0 | 12.3 | 12.4 |
| 26 | 13.1 | 13.3 | 13.3 | 13.2 | 13.0 | 12.5 | 12.0 | 11.8 | 11.8 | 12.0 | 12.3 | 12.4 |
| 27 | 13.1 | 13.3 | 13.3 | 13.2 | 13.0 | 12.5 | 12.0 | 11.8 | 11.8 | 12.0 | 12.3 | 12.5 |
| 28 | 13.2 | 13.3 | 13.4 | 13.2 | 13.0 | 12.5 | 12.0 | 11.8 | 11.8 | 12.1 | 12.3 | 12.5 |
| 29 | 13.2 | ..... | 13.4 | 13.2 | 13.0 | 12.5 | 12.0 | 11.8 | 11.9 | 12.1 | 12.3 | 12.5 |
| 30 | 13.2 | ..... | 13.4 | 13.2 | 13.0 | 12.5 | 12.0 | 11.8 | 11.9 | 12.1 | 12.3 | 12.5 |
| 31 | 13.2 | ..... | 13.4 | ..... | 13.0 | ..... | 11.9 | 11.8 | ..... | 12.1 | ..... | 12.5 |

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*Station rating table for Klamath River at Keno, Oreg., from May 31, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 11.60 | 900 | 12.60 | 1,960 | 13.60 | 3,730 | 14.60 | 6,590 |
| 11.70 | 970 | 12.70 | 2,100 | 13.70 | 3,960 | 14.70 | 6,940 |
| 11.80 | 1,050 | 12.80 | 2,250 | 13.80 | 4,200 | 14.80 | 7,300 |
| 11.90 | 1,140 | 12.90 | 2,400 | 13.90 | 4,460 | 14.90 | 7,670 |
| 12.00 | 1,240 | 13.00 | 2,560 | 14.00 | 4,730 | 15.00 | 8,050 |
| 12.10 | 1,350 | 13.10 | 2,730 | 14.10 | 5,010 | 15.10 | 8,440 |
| 12.20 | 1,460 | 13.20 | 2,910 | 14.20 | 5,300 | 15.20 | 8,840 |
| 12.30 | 1,580 | 13.30 | 3,100 | 14.30 | 5,600 | 15.30 | 9,250 |
| 12.40 | 1,700 | 13.40 | 3,300 | 14.40 | 5,920 | | |
| 12.50 | 1,830 | 13.50 | 3,510 | 14.50 | 6,250 | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on 22 discharge measurements made during 1904–5. It is well defined between gage heights 12.2 feet and 13.3 feet.

*Estimated monthly discharge of Klamath River at Keno, Oreg., for 1904 and 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| **1904.** | | | | |
| June | 8,440 | 5,300 | 7,076 | 421,100 |
| July | 5,300 | 3,300 | 4,177 | 256,800 |
| August | 3,100 | 2,100 | 2,513 | 154,500 |
| September | 2,100 | 1,700 | 1,778 | 105,800 |
| October | 1,830 | 1,700 | 1,775 | 109,100 |
| November | 2,100 | 1,960 | 2,007 | 119,400 |
| December | 2,400 | 2,100 | 2,235 | 137,400 |
| The period | | | | 1,304,000 |
| **1905.** | | | | |
| January | 3,100 | 2,400 | 2,716 | 167,000 |
| February | 3,100 | 2,910 | 3,086 | 171,400 |
| March | 3,300 | 2,910 | 3,052 | 187,700 |
| April | 3,300 | 2,910 | 3,097 | 184,300 |
| May | 2,910 | 2,560 | 2,688 | 165,300 |
| June | 2,560 | 1,830 | 2,157 | 128,400 |
| July | 1,830 | 1,140 | 1,436 | 88,300 |
| August | 1,140 | 1,050 | 1,065 | 65,480 |
| September | 1,140 | 1,050 | 1,056 | 62,840 |
| October | 1,350 | 1,140 | 1,203 | 73,970 |
| November | 1,580 | 1,350 | 1,445 | 85,980 |
| December | 1,830 | 1,580 | 1,694 | 104,200 |
| The year | 3,300 | 1,050 | 2,058 | 1,485,000 |

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### SYCAN RIVER NEAR SILVERLAKE, OREG.

This station was established May 2, 1905, by Ivan Landes. It is located about 30 miles south of Silverlake, Oreg., in sec. 19, T. 32 S., R. 14 E.

The channel is straight for about 20 feet above and 150 feet below the station. The current is swift. The right bank is high, rocky, and clean and does not overflow. The left bank is low, clean, and subject to overflow at extreme high stages. The bed of the stream is of rocks, gravel, and sand, free from vegetation, and permanent. There is but one channel at low and two channels at high stages.

Discharge measurements are made from a private bridge. The initial point for soundings is at the west end of the bridge.

A staff gage is fastened vertically to a bent of the bridge. During 1905 the gage was read by O. F. Griffith and J. S. Wakefield. The bench mark is a marked point of rock on the right bank a short distance upstream from the bridge; elevation, 6.79 feet above the datum of the gage.

*Discharge measurements of Sycan River near Silverlake, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| March 16 | Ivan Landes | 21 | 28 | 1.38 | 2.40 | 38 |
| April 10 | do | 30 | 46 | 2.36 | 3.05 | 110 |
| May 2 | do | 56 | 93 | 1.76 | 3.45 | 163 |
| June 12 | do | 52 | 44 | 1.56 | 2.32 | 69 |
| July 30 | Landes and King | 19 | 11.9 | .86 | 1.27 | 10.2 |
| October 3 | Ivan Landes | 14 | 14.9 | .36 | 1.70 | 5.4 |
| November 7 | do | 12 | 7.1 | .85 | 1.12 | 6.0 |

*Daily gage height, in feet, of Sycan River, near Silverlake, Oreg., for 1905.*

| Day. | May. | June. | July. | Aug. | Sept. | Oct. | Day. | May. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 2.6 | 1.8 | 1.25 | 1.4 | ..... | 17 | 3.5 | 2.15 | 1.45 | 1.0 | 1.75 | 1.8 |
| 2 | 3.45 | 2.6 | 1.8 | 1.25 | 1.4 | 1.7 | 18 | 3.4 | 2.05 | 1.45 | 1.05 | 1.8 | 1.8 |
| 3 | 3.35 | 2.6 | 1.75 | 1.1 | 1.5 | 1.85 | 19 | 3.3 | 2.2 | a1.3 | 1.05 | 1.8 | 1.7 |
| 4 | 3.25 | 3.0 | 1.75 | 1.15 | 1.5 | 1.7 | 20 | 3.4 | 2.1 | 1.35 | 1.1 | 1.75 | 1.85 |
| 5 | 3.2 | 3.1 | 1.7 | .8 | 1.55 | 1.85 | 21 | 2.9 | 2.0 | 1.4 | 1.1 | 1.75 | 1.7 |
| 6 | 3.2 | 3.1 | 1.7 | .8 | 1.55 | 1.8 | 22 | 3.0 | 1.8 | 1.4 | 1.15 | 1.75 | 1.7 |
| 7 | 3.25 | 3.2 | 1.7 | .8 | 1.55 | 2.0 | 23 | 3.1 | 1.9 | 1.4 | 1.15 | 1.75 | 1.85 |
| 8 | 3.6 | 3.0 | 1.6 | .8 | 1.55 | 1.9 | 24 | 3.0 | 1.9 | 1.4 | 1.2 | 1.75 | 1.85 |
| 9 | 3.4 | 3.0 | 1.6 | .8 | 1.6 | 1.8 | 25 | 2.9 | 1.9 | 1.3 | 1.25 | 1.75 | 1.85 |
| 10 | 3.35 | a2.5 | 1.5 | .8 | 1.65 | 1.7 | 26 | 3.2 | 1.95 | 1.25 | 1.25 | 1.75 | 1.85 |
| 11 | 3.35 | 2.4 | 1.5 | .8 | 1.7 | 1.7 | 27 | 3.55 | 1.9 | 1.25 | 1.3 | 2.0 | 1.85 |
| 12 | 3.3 | 2.3 | 1.5 | .8 | 1.7 | 1.8 | 28 | 3.1 | 1.9 | 1.25 | 1.3 | 1.9 | 1.7 |
| 13 | 3.4 | 2.4 | 1.5 | .8 | 1.75 | 1.7 | 29 | 2.9 | 1.85 | 1.25 | 1.35 | 1.8 | ..... |
| 14 | 3.25 | 2.6 | 1.5 | 1.0 | 1.75 | 1.7 | 30 | 2.8 | 1.85 | 1.25 | 1.35 | 1.8 | ..... |
| 15 | 3.3 | 2.4 | 1.5 | 1.0 | 1.75 | 1.65 | 31 | 2.7 | ..... | 1.25 | 1.4 | 1.8 | ..... |
| 16 | 3.35 | 2.2 | 1.5 | 1.0 | 1.75 | 1.8 | | | | | | | |

a Water turned into ditch.

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### LOST RIVER NEAR CLEAR LAKE, CAL.

This station was established September 1, 1904, by T. H. Humphreys. It is located about 2 miles downstream from Jessie D. Carr's Clear Lake dam, a short distance below the dam site for Clear Lake reservoir, about 20 miles from Tule Lake post-office, Cal.

The channel is straight for about 150 feet above and below the station. The current is swift. Both banks are high, rocky, and clean. There is a flood plain about 150 feet in width along the left bank. The bed of the stream is composed of rock, gravel, and soil. The channel contains a considerable growth of tules during the spring and summer months.

Discharge measurements are made during flood stages by means of a cable and car, and at low stages by wading. The initial point for soundings is the left-bank end of the cable.

A gage is painted on the vertical rock cliff on the right bank. November 4, 1905, an automatic water-height register was installed for recording gage heights. The bench mark is a mark on the rock to which the left end of the cable is anchored; elevation, 16.62 feet above the datum of the gage.

Gage heights and discharge measurements taken at this station in 1904 are contained in Water-Supply Paper No. 134, United States Geological Survey.

*Discharge measurements of Lost River near Clear Lake, Cal., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 26 | C. T. Darley | 102 | 92 | 1.75 | 6.30 | 161 |
| February 3 | do | 130 | 196 | 2.31 | 7.20 | 453 |
| February 7 | do | 100 | 104 | 2.08 | 6.39 | 216 |
| February 24 | do | 98 | 70 | 1.77 | 6.01 | 124 |
| March 7 | do | 102 | 102 | 1.92 | 6.35 | 196 |
| March 13 | do | 110 | 115 | 2.19 | 6.50 | 252 |
| April 3 | do | 130 | 203 | 2.64 | 7.30 | 535 |
| April 8 | do | 92 | 85 | 2.05 | 6.24 | 174 |
| April 28 | do | 14 | 12.8 | 1.88 | 5.26 | 24 |
| June 2 | do | 9.5 | 8.8 | .90 | 5.00 | 7.9 |
| September 11 | do | 10 | 8.8 | .66 | 5.02 | 5.8 |
| October 30 | do | 16 | 10.1 | .75 | 5.10 | 7.6 |



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*Daily gage height, in feet, of Lost River near Clear Lake, Cal., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.4 | 7.3 | 6.3 | 6.9 | 5.3 | 5.0 | | | | | 5.1 | 5.15 |
| 2 | 5.4 | 7.8 | 6.2 | 7.5 | 5.3 | 5.0 | | | | | 5.1 | 5.15 |
| 3 | 5.4 | 7.3 | 6.3 | 7.2 | 5.2 | 5.05 | | | | | 5.1 | 5.2 |
| 4 | 5.4 | 7.1 | 6.3 | 6.9 | 5.2 | 5.1 | | | | | 5.1 | 5.2 |
| 5 | 5.4 | 6.8 | 6.4 | 6.7 | 5.1 | 5.15 | | | | | 5.1 | 5.2 |
| 6 | 5.4 | 6.5 | 6.3 | 6.6 | 5.1 | 5.2 | | | | | 5.1 | 5.2 |
| 7 | 5.4 | 6.3 | 6.5 | 6.4 | 5.15 | 5.35 | | | | | 5.1 | 5.2 |
| 8 | 5.4 | 6.1 | 6.4 | 6.2 | 5.2 | 5.6 | | | | | 5.1 | 5.15 |
| 9 | 5.4 | 5.8 | 6.3 | 6.0 | 5.2 | 5.9 | | | | | 5.1 | 5.15 |
| 10 | 5.4 | 5.6 | 6.2 | 5.8 | 5.2 | 5.8 | | | | | 5.1 | 5.15 |
| 11 | 5.4 | 5.2 | 6.2 | 5.7 | 5.3 | 5.7 | | | | | 5.1 | 5.15 |
| 12 | 5.4 | 6.05 | 6.3 | 5.8 | 5.4 | 5.6 | | | | | 5.1 | 5.15 |
| 13 | 5.4 | 6.95 | 6.5 | 5.7 | 5.35 | 5.4 | | | | | 5.1 | 5.15 |
| 14 | 5.6 | 6.9 | 6.2 | 5.5 | 5.3 | 5.25 | | | | | 5.1 | 5.15 |
| 15 | 5.8 | 6.7 | 6.1 | 5.5 | 5.25 | 5.1 | | | | | 5.1 | 5.15 |
| 16 | 6.0 | 6.2 | 6.3 | 5.55 | 5.2 | 5.0 | | | | | 5.1 | 5.2 |
| 17 | 6.25 | 5.6 | 6.9 | 5.6 | 5.15 | 5.0 | | | | | 5.1 | 5.2 |
| 18 | 6.3 | 5.5 | 6.7 | 5.6 | 5.1 | 5.0 | | | | | 5.1 | 5.2 |
| 19 | 6.3 | 5.8 | 6.3 | 5.7 | 5.05 | 5.0 | | | | | 5.1 | 5.2 |
| 20 | 6.3 | 6.4 | 6.4 | 5.5 | 5.05 | 5.0 | | | | | 5.2 | 5.2 |
| 21 | 6.35 | 6.3 | 6.6 | 5.5 | 5.0 | 5.0 | | | | | 5.15 | 5.2 |
| 22 | 6.4 | 6.2 | 6.9 | 5.5 | 5.0 | 5.0 | | | | | 5.15 | 5.2 |
| 23 | 6.4 | 6.0 | 6.9 | 5.45 | 5.0 | 5.0 | | | | | 5.15 | 5.2 |
| 24 | 6.45 | 6.1 | 6.5 | 5.4 | 4.95 | 5.0 | | | | | 5.15 | 5.2 |
| 25 | 6.5 | 6.2 | 6.3 | 5.4 | 4.9 | 5.0 | | | | | 5.15 | 5.2 |
| 26 | 6.3 | 6.0 | 6.5 | 5.5 | 4.9 | 5.0 | | | | | 5.2 | 5.2 |
| 27 | 6.0 | 6.1 | 6.9 | 5.4 | 4.95 | 5.0 | | | | | 5.2 | 5.2 |
| 28 | 6.2 | 6.2 | 6.6 | 5.3 | 5.0 | 5.0 | | | | | 5.2 | 5.2 |
| 29 | 6.4 | ..... | 6.7 | 5.3 | 5.05 | 5.0 | | | | 5.1 | 5.15 | 5.2 |
| 30 | 6.6 | ..... | 6.0 | 5.3 | 5.1 | 5.0 | | | | 5.1 | 5.15 | 5.2 |
| 31 | 6.8 | ..... | 6.4 | ..... | 5.05 | ..... | | | | 5.1 | ..... | 5.2 |

*Station rating table for Lost River near Clear Lake, Cal., from September 4, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 4.90 | 6 | 5.70 | 66 | 6.50 | 238 | 7.30 | 508 |
| 5.00 | 9 | 5.80 | 81 | 6.60 | 268 | 7.40 | 545 |
| 5.10 | 12 | 5.90 | 98 | 6.70 | 300 | 7.50 | 582 |
| 5.20 | 17 | 6.00 | 117 | 6.80 | 332 | 7.60 | 619 |
| 5.30 | 23 | 6.10 | 138 | 6.90 | 365 | 7.70 | 657 |
| 5.40 | 31 | 6.20 | 160 | 7.00 | 400 | 7.80 | 695 |
| 5.50 | 41 | 6.30 | 184 | 7.10 | 436 | 7.90 | 733 |
| 5.60 | 53 | 6.40 | 210 | 7.20 | 472 | 8.00 | 772 |

NOTE.—The above table is based on 16 discharge measurements made during 1904-5. It is fairly well defined.

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*Estimated monthly discharge of Lost River near Clear Lake, Cal., for 1904 and 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| 1904. | | | | |
| September | 20 | 9 | 11.3 | 673 |
| October | 23 | 12 | 18.1 | 1,113 |
| November | 17 | 12 | 15.5 | 923 |
| December | 27 | 14 | 18.2 | 1,119 |
| 1905. | | | | |
| January | 332 | 31 | 120 | 7,379 |
| February | 695 | 17 | 217 | 12,050 |
| March | 365 | 117 | 224 | 13,770 |
| April | 582 | 23 | 127 | 7,557 |
| May | 31 | 6 | 14.6 | 898 |
| June | 98 | 9 | 21.6 | 1,286 |
| July | | | [a] 7.0 | 430 |
| August | | | [a] 6.0 | 369 |
| September | | | [a] 7.0 | 417 |
| October | | | [a] 10.0 | 615 |
| November | 17 | 12 | 13.0 | 774 |
| December | 12 | 14 | 16.0 | 984 |
| The year | | | 65.3 | 46,530 |

[a] Estimated.

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### LOST RIVER NEAR MERRILL, OREG.

This station was established July 26, 1904, by T. H. Humphreys. It is located about 1½ miles downstream from the Stukel Bridge, 4 miles northwest of Merrill, Oreg.

The channel is straight for 200 feet above and 400 feet below the station. The current is swift at high and medium at low stages. Both banks are high and not liable to overflow. The bed of the stream is composed of clay, rock, and gravel, and is not subject to change. There is but one channel at all stages. During low water the flow over the greater portion of the section is shallow and broken, making it difficult to obtain accurate results with a current meter. Near the right bank the channel is deeper. At low water in the fall of the year a considerable growth of water grass accumulates in the channel. An old rock dam located 200 feet above the gaging station does not materially interfere with the accuracy of discharge measurements.

Discharge measurements are made at flood stages by means of a cable and car and at low water by wading. The initial point for soundings is the stream face of the left-bank cable support.

A staff gage is fastened vertically at the left bank about 40 feet upstream from the cable. During 1905 the gage was read by Mrs. Joseph Stukel. Bench marks were established as follows: (1) A large wire nail driven into post supporting cable at left bank; elevation, 17.92 feet. (2) A nail driven into the sill at the northwest corner of a granary 200 feet downstream from the cable on the right bank; elevation, 20.61 feet. Elevations refer to the datum of the gage.

Gage heights and discharge measurements taken at this station in 1904 are contained in Water-Supply Paper No. 134, United States Geological Survey.

*Discharge measurements of Lost River near Merrill, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft per sec.* | *Feet.* | *Sec.-ft.* |
| January 18 | C. T. Darley | 87 | 82 | 1.60 | 3.50 | 131 |
| February 1 | do | 102 | 208 | 2.72 | 4.80 | 566 |
| February 8 | do | 108 | 240 | 2.74 | 5.05 | 658 |
| February 27 | do | 92 | 197 | 2.70 | 4.55 | 533 |
| March 5 | do | 96 | 199 | 2.71 | 4.63 | 540 |
| April 5 | do | 120 | 425 | 2.67 | 6.77 | 1,134 |
| April 14 | do | 90 | 140 | 2.03 | 4.00 | 284 |
| April 29 | do | 80 | 95 | 1.53 | 3.50 | 145 |
| May 12 | do | 89 | 95 | 1.37 | 3.50 | 130 |
| June 14 | do | 89 | 86 | 1.36 | 3.41 | 117 |
| July 23 | do | 90 | 86 | 1.36 | 3.45 | 117 |
| August 15 | C. T. Darley and W. B. Clapp | 88 | 82 | 1.26 | 3.41 | 103 |
| August 26 | C. T. Darley | 87 | 84 | 1.21 | 3.31 | 102 |
| September 15 | do | 87 | 83 | 1.22 | 3.32 | 101 |

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*Daily gage height, in feet, of Lost River near Merrill, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.5 | 4.7 | 4.5 | 4.8 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 2 | 3.5 | 5.7 | 4.5 | 4.8 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 3 | 3.5 | 6.3 | 4.5 | 6.0 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 4 | 3.5 | 6.8 | 4.5 | 7.0 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 5 | 3.5 | 7.0 | 4.6 | 6.8 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 6 | 3.5 | 6.2 | 4.6 | 6.0 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 7 | 3.5 | 5.6 | 4.6 | 5.3 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 8 | 3.5 | 5.1 | 4.55 | 5.4 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 9 | 3.5 | 4.7 | 4.55 | 5.6 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 10 | 3.5 | 4.4 | 4.4 | 5.8 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 11 | 3.5 | 4.2 | 4.3 | 5.9 | 3.5 | 3.5 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 12 | 3.5 | 4.0 | 4.35 | 4.0 | 3.5 | 3.55 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 13 | 3.5 | 3.9 | 4.2 | 4.0 | 3.5 | 3.55 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 14 | 3.5 | 3.8 | 4.2 | 4.0 | 3.5 | 3.55 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 15 | 3.5 | 3.8 | 4.2 | 4.0 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 16 | 3.5 | 3.7 | 4.1 | 3.9 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 17 | 3.5 | 3.7 | 4.1 | 3.9 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 18 | 3.5 | 3.7 | 4.1 | 3.8 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 19 | 3.5 | 3.7 | 4.1 | 3.8 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 20 | 3.5 | 3.8 | 4.2 | 3.8 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 21 | 3.5 | 3.8 | 4.4 | 3.7 | 3.5 | 3.4 | 3.4 | 3.4 | 3 3 | 3.3 | 3.3 | 3.3 |
| 22 | 3.5 | 3.9 | 4.5 | 3.7 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 23 | 3.5 | 4.4 | 4.6 | 3.7 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 24 | 3.5 | 4.4 | 4.7 | 3.6 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 25 | 4.5 | 4.5 | 4.9 | 3.6 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 26 | 5.4 | 4.5 | 4.6 | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 27 | 5.3 | 4.55 | 4.6 | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 28 | 5.0 | 4.55 | 5.0 | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 29 | 4.7 | ..... | 4.9 | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 30 | 4.5 | ..... | 4.8 | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 | 3.3 | 3.3 | 3.3 | 3.3 |
| 31 | 4.4 | ..... | 4.8 | ..... | 3.5 | ..... | 3.4 | 3.4 | ..... | 3.3 | ..... | 3.3 |

*Station rating table for Lost River near Merrill, Oreg., from July 16, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.30 | 102 | 3.60 | 176 | 3.90 | 262 | 4.20 | 362 |
| 3.40 | 125 | 3.70 | 203 | 4.00 | 294 | | |
| 3.50 | 150 | 3.80 | 232 | 4.10 | 328 | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on 20 discharge measurements made during 1904-5. It is not well defined. Above gage height 4.2 feet the rating curve is a tangent, the difference being 35 per tenth

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*Estimated monthly discharge of Lost River near Merrill, Oreg., for 1904 and 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| **1904.** | | | | |
| July 26–31 | 203 | 203 | 203 | 2,415 |
| August | 203 | 176 | 199 | 12,240 |
| September | 176 | 163 | 165 | 9,818 |
| October | 163 | 150 | 158 | 9,715 |
| November | 150 | 150 | 150 | 8,926 |
| December | 150 | 150 | 150 | 9,223 |
| The period | | | | 52,330 |
| **1905.** | | | | |
| January | 782 | 150 | 248 | 15,250 |
| February | 1,342 | 203 | 514 | 28,550 |
| March | 642 | 328 | 461 | 28,350 |
| April | 1,342 | 150 | 470 | 27,970 |
| May | 150 | 150 | 150 | 9,223 |
| June | 163 | 125 | 138 | 8,212 |
| July | 125 | 125 | 125 | 7,686 |
| August | 125 | 125 | 125 | 7,686 |
| September | 102 | 102 | 102 | 6,069 |
| October | 102 | 102 | 102 | 6,272 |
| November | 102 | 102 | 102 | 6,069 |
| December | 102 | 102 | 102 | 6,272 |
| The year | 1,342 | 102 | 220 | 157,600 |

## TULE LAKE NEAR MERRILL, OREG.

This station was established May 17, 1904, by John H. Lewis and Ivan Landes for recording the water level in Tule Lake. It is located on Tule Lake at the mouth of Lost River about 3 miles east of Merrill, Oreg , 25 miles south from Klamath Falls, and near the Oregon-California line.

The gage is a vertical timber fastened to posts driven in the lake bed, about 20 feet from the shore of the lake. It is in line with the east lane fence, one-fourth mile south of the residence of J. Frank Adams. The bench mark is a notch cut in large juniper gatepost on the north side of the gate entrance about 60 feet distant from the gage rod; elevation, 13.70 feet above the zero of the gage.

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*Daily gage height, in feet, of Tule Lake near Merrill, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | 9.25 | | | | | | | | |
| 3 | | | | | | 9.05 | 8.6 | | | | | |
| 4 | | | | | 9.2 | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | 9.1 | | | | | | | | | |
| 7 | | | | | | | | 7.95 | | | | |
| 8 | | | | | | | | | | 7.05 | 6.85 | 6.85 |
| 9 | | | | | | | | | 7.4 | | | |
| 10 | | | | | | 9.0 | 8.5 | | | | | |
| 11 | | | | | | | | | | | | |
| 12 | | 8.9 | | | | | | | | | | |
| 13 | 8.6 | | | | | | | | | | | |
| 14 | | | | | | | | 7.8 | 7.3 | | | |
| 15 | | | 9.15 | | | | | | | | | 6.7 |
| 16 | | | | | 9.15 | | | | | 7.0 | 6.8 | |
| 17 | | | | | | | 8.4 | | | | | |
| 18 | | 8.9 | | | | | | | | | | |
| 19 | | | | | | 8.95 | | | | | | |
| 20 | | | | | | | | | | | | |
| 21 | | | | | | | | 7.6 | | | | |
| 22 | | | | | | | | | 7.2 | | | |
| 23 | | | | 9.2 | 9.1 | | | | | 6.9 | 6.8 | |
| 24 | | | 9.1 | | | | 8.3 | | | | | |
| 25 | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | 6.6 |
| 27 | | 9.0 | | | | 8.7 | | | | | | |
| 28 | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | |
| 30 | | | | | | | | | 7.1 | 6.95 | 6.8 | |
| 31 | 8.65 | | | | | | 8.05 | 7.5 | | | | 6.55 |

NOTE.—Ice out of river, Jan. 31.

### MILLER CREEK NEAR LORELLA, OREG.

This station was established August 10, 1904, by F. S. Chapman. It is located at Horsefly, 10 miles northeast of Lorella, Oreg.

The channel is straight for 600 feet above and 100 feet below the station. The current is sluggish at low and swift at high stages. Both banks are high, rocky, wooded, and not subject to overflow. The bed of the stream is of rock and gravel, and not liable to change. The channel is obstructed by much vegetation during the season of low stage.

Discharge measurements are made during high stages by means of a cable and car, and at low stages by wading. The initial point for soundings is the stream side of the cable support on the right bank.

A staff gage is fastened vertically at the right bank, 300 feet upstream from the cable, where the water stands in a pool. During 1905 the gage was read by Louis Gerber. On December 9, 1905, an automatic water-height register was installed for recording gage heights. The bench mark is a point on top of a large bowlder 25 feet downstream from the gage; elevation, 12.68 feet above the datum of the gage.

Gage heights and discharge measurements taken at this station during 1904 are contained in Water-Supply Paper No. 134, United States Geological Survey.

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*Discharge measurements of Miller Creek near Lorella, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| January 28 | C. T. Darley | 110 | 72 | 2.03 | 7.25 | 146 |
| February 4 | do | 124 | 86 | 1.87 | 7.30 | 161 |
| February 6 | do | 90 | 58 | 1.50 | 6.99 | 87 |
| February 25 | do | 118 | 88 | 2.01 | 7.30 | 177 |
| March 8 | do | 91 | 72 | 1.72 | 7.14 | 124 |
| March 15 | F. S. Chapman | 90 | 65 | 1.46 | 6.92 | 95 |
| April 2 | C. T. Darley | 130 | 155 | 2.97 | 8.00 | 460 |
| April 9 | do | 72 | 47 | 1.32 | 6.88 | 62 |
| April 28 | do | 18 | 10.8 | .29 | 6.19 | 3.1 |
| June 1 | do | 20 | 11.2 | .18 | 6.11 | 2.0 |

*Daily gage height, in feet, of Miller Creek near Lorella, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.3 | 8.0 | 7.2 | 7.0 | 6.3 | 6.2 | | | | | | |
| 2 | 6.3 | 8.2 | 7.2 | 8.0 | 6.3 | 6.1 | | | | | | |
| 3 | 6.3 | 7.7 | 7.2 | 7.8 | 6.3 | 6.1 | | | | | | |
| 4 | 6.3 | 7.3 | 7.3 | 7.6 | 6.3 | 6.2 | | | | | | |
| 5 | 6.3 | 7.7 | 7.3 | 7.4 | 6.3 | 6.2 | | | | | | |
| 6 | 6.3 | 7.0 | 7.2 | 7.2 | 6.3 | 6.3 | | | | | | |
| 7 | 6.3 | 7.0 | 7.2 | 7.0 | 6.2 | 6.3 | | | | | | |
| 8 | 6.3 | 7.0 | 7.2 | 6.9 | 6.2 | 6.3 | | | | | | |
| 9 | 6.3 | 7.0 | 7.1 | 6.8 | 6.4 | 6.3 | | | | | | [a]6.0 |
| 10 | 6.3 | 6.9 | 7.1 | 6.8 | 6.4 | 6.3 | | | | | | 6.0 |
| 11 | 6.3 | 6.6 | 7.0 | 6.8 | 6.4 | 6.3 | | | | | | 6.0 |
| 12 | 6.3 | 6.5 | 7.1 | 6.6 | 6.4 | 6.3 | | | | | | 6.0 |
| 13 | 6.3 | 6.5 | 7.1 | 6.6 | 6.4 | 6.2 | | | | | | 6.0 |
| 14 | 6.3 | 6.4 | 7.1 | 6.5 | 6.4 | 6.2 | | | | | | 6.0 |
| 15 | 6.3 | 6.4 | 6.8 | 6.5 | 6.3 | 6.2 | | | | | | 6.0 |
| 16 | 7.5 | 6.4 | 7.3 | 6.6 | 6.3 | 6.2 | | | | | | 6.0 |
| 17 | 7.6 | 6.4 | 7.3 | 6.6 | 6.3 | | | | | | | 6.0 |
| 18 | 7.7 | 6.4 | 7.3 | 6.6 | 6.3 | | | | | | | 6.0 |
| 19 | 7.5 | 6.8 | 7.4 | 6.5 | 6.3 | | | | | | | 6.0 |
| 20 | 7.5 | 7.2 | 7.4 | 6.5 | 6.2 | | | | | | | 6.0 |
| 21 | 7.5 | 7.3 | 7.1 | 6.5 | 6.1 | | | | | | | 6.0 |
| 22 | 7.9 | 7.3 | 7.3 | 6.4 | 6.0 | | | | | | | 6.0 |
| 23 | 8.2 | 7.3 | 7.3 | 6.4 | 6.0 | | | | | | | 6.0 |
| 24 | 7.9 | 7.3 | 7.2 | 6.4 | 6.0 | | | | | | 6.0 | 6.0 |
| 25 | 7.9 | 7.3 | 7.2 | 6.3 | 5.9 | | | | | | 6.1 | 6.0 |
| 26 | 7.7 | 7.3 | 7.9 | 6.3 | 6.1 | | | | | | | 6.0 |
| 27 | 7.7 | 7.3 | 7.5 | 6.2 | 6.1 | | | | | | | 6.0 |
| 28 | 7.3 | 7.3 | 7.4 | 6.2 | 6.2 | | | | | | | 6.0 |
| 29 | 7.5 | | 7.4 | 6.2 | 6.3 | | | | | | | 6.0 |
| 30 | 8.0 | | 7.2 | 6.2 | 6.2 | | | | | | | 6.0 |
| 31 | 8.3 | | 7.2 | | 6.2 | | | | | | | |

[a] New gage.

NOTE.—No flow June 17 to December 31

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*Station rating table for Miller Creek near Lorella, Oreg., from August 7, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 6.00 | 0 | 6.80 | 52 | 7.60 | 274 | 8.40 | 665 |
| 6.10 | 1.5 | 6.90 | 67 | 7.70 | 317 | 8.50 | 717 |
| 6.20 | 4 | 7.00 | 86 | 7.80 | 363 | 8.60 | 770 |
| 6.30 | 8 | 7.10 | 109 | 7.90 | 411 | 8.70 | 823 |
| 6.40 | 13 | 7.20 | 135 | 8.00 | 460 | 8.80 | 876 |
| 6.50 | 20 | 7.30 | 163 | 8.10 | 510 | 8.90 | 929 |
| 6.60 | 29 | 7.40 | 196 | 8.20 | 561 | 9.00 | 982 |
| 6.70 | 39 | 7.50 | 234 | 8.30 | 613 | | |

NOTE.—The above table is based on 13 discharge measurements made during 1904–5. It is well defined between gage heights 6.1 feet and 8 feet.

*Estimated monthly discharge of Miller Creek near Lorella, Oreg., for 1904 and 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| 1904. | | | | |
| August | 1.5 | .75 | 1.3 | 79 |
| September | 1.5 | .0 | .2 | 12 |
| October | 8 | 1.5 | 2.4 | 148 |
| November | 8 | 1.5 | 3.7 | 221 |
| December | 10.5 | 1.5 | 6.2 | 381 |
| The period | | | | 841 |
| 1905. | | | | |
| January | 613 | 8 | 179 | 11,010 |
| February | 561 | 13 | 138 | 7,664 |
| March | 411 | 52 | 153 | 9,408 |
| April | 460 | 4 | 71.0 | 4,225 |
| May | 13 | 0 | 6.5 | 400 |
| June | 8 | 0 | 3.0 | 179 |
| July | 0 | 0 | .0 | 0 |
| August | 0 | 0 | .0 | 0 |
| September | 0 | 0 | .0 | 0 |
| October | 0 | 0 | .0 | 0 |
| November | 0 | 0 | .0 | 0 |
| December | 0 | 0 | .0 | 0 |
| The year | 613 | 0 | 46. | 32,890 |

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### PRECIPITATION AND EVAPORATION DATA.

The following table gives the total precipitation in inches, by months, and also the annual totals:

| | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Keno, Oreg.: | | | | | | | | | | | | | |
| 1904 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.00 | 1.58 | 2.08 | 1.50 | 3.57 | ..... |
| 1905 | 2.08 | 1.91 | 2.30 | 0.66 | 2.29 | 0.15 | 0.00 | 0.00 | 0.75 | 0.72 | 1.30 | 2.23 | 14.39 |
| Tule Lake, Cal.: | | | | | | | | | | | | | |
| 1904 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.00 | 0.92 | 1.01 | 0.42 | 3.11 | ..... |
| 1905 | 1.25 | 1.19 | 1.70 | 0.20 | 2.62 | 0.30 | 0.00 | 0.00 | 0.42 | ..... | 1.25 | 0.93 | ..... |
| Horse Fly, near Lorella, Oreg.: | | | | | | | | | | | | | |
| 1904 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.00 | 0.71 | 1.11 | 1.07 | 2.61 | ..... |
| 1905 | 1.43 | 1.09 | 2.22 | 0.28 | 2.56 | 1.23 | 0.00 | 0.00 | 0.32 | 0.32 | 0.83 | 2.41 | 12.69 |

The following table gives the total evaporation in inches, by months, at Keno, Oreg.:

| Year. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1904 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 6.66 | 5.12 | 2.01 | 2.01 | 2.01 | ..... |
| 1905 | 1.19 | 0.78 | 0.78 | 2.69 | 4.12 | 6.20 | 7.57 | 7.03 | 6.15 | 1.98 | 0.46 | ..... | ..... |

### MISCELLANEOUS MEASUREMENTS IN NORTHERN PACIFIC OCEAN DRAINAGE BASIN.

*Antelope Creek near Mount Hebron, Cal.*—This creek rises on the eastern slope of Mount Shasta. It is tributary to Lower Klamath Lake, although its waters sink before reaching the lake. A measurement was made June 17 by C. T. Darley, 12 miles below its source.

Width, 25.5 feet; area, 37 square feet; mean velocity, 3.03 feet per second; discharge, 112 second-feet.

Another measurement was made August 28 by C. T. Darley 15 miles below its source.

Width, 13 feet; area, 9.4 square feet; mean velocity, 1.11 feet per second; discharge, 10.4 second-feet.

*Adams ditch near Merrill, Oreg.*—This canal diverts water from White Lake, an arm of Lower Klamath Lake. For the first mile this canal is common with the Van Brimmer canal. It is about 16 miles in length and is used for the irrigation of land in the vicinity of Merrill, Oreg. The following measurements were made during 1905 at a point one mile below the head of the canal and 300 feet below the point where the Adams and Van Brimmer canals separate. The gage rod is a 1 by 4 inch timber divided into feet and hundredths. There is no bench mark.

May 14: Width, 36 feet; area, 42 square feet; mean velocity, 1.10 feet per second; gage height, 1.73 feet; discharge, 46 second-feet.

May 21: Width, 37.6 feet; area, 47 square feet; mean velocity, 1.13 feet per second; gage height, 1.90 feet; discharge, 53 second-feet.

June 15: Width, 37.5 feet; area, 40 square feet; mean velocity, 1.28 feet per second; gage height, 2.14 feet; discharge, 51 second-feet.

July 22: Width, 37.5 feet; area, 43 square feet; mean velocity, 1.19 feet per second; gage height, 2.22 feet; discharge, 51 second-feet.

August 24: Width, 37.5 feet; area, 36 square feet; mean velocity, 1.03 feet per second; gage height, 2.13 feet; discharge, 37 second-feet.

August 25: Width, 36.7 feet; area, 32 square feet; mean velocity, 0.91 foot per second; gage height, 2.00 feet; area, 29 second-feet.

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August 25: Width, 37.9 feet; area, 39 square feet: mean velocity, 1.05 feet per second; gage height, 2.26 feet; discharge, 41 second-feet.

*Ankeny ditch, station No. 1, near Klamath Falls, Oreg.*—Ankeny canal diverts water from Link River at the outlet of Upper Klamath Lake, 1½ miles above the town of Klamath Falls, Oreg. The water from this canal is used for electric power and irrigation purposes in the vicinity of Klamath Falls. This station is located about 500 feet above point of diversion to electric power plant. Discharges here given represent the amount of water used for both electric power and irrigation purposes. The following measurements were made during 1905 by C. T. Darley.:

June 29: Width, 17.4 feet; area, 21 square feet; mean velocity, 2.71 feet per second; gage height, 1.36 feet; discharge, 57 second-feet.

June 30: Width, 17.4 feet; area, 20 square feet; mean velocity, 2.70 feet per second; gage height, 1.34 feet; discharge, 54 second feet.

May 11: Width, 17.5 feet; area, 22 square feet; mean velocity, 2.86 feet per second; gage height, 1.39 feet; discharge, 63 second-feet.

June 29: Width, 17.4 feet; area, 21 square feet; mean velocity, 2.52 feet per second; gage height, 1.36 feet; discharge, 53 second-feet.

*Ankeny canal station No. 2, near Klamath Falls, Oreg.*—This station is located about 200 feet below point of diversion by electric power plant. Discharges here given represent the amount of water used for irrigation purposes.

April 23: Width, 13.5 feet; area, 7.0 square feet; mean velocity, 1.24 feet per second; gage height, 1.28 feet; discharge, 8.7 second-feet.

May 2: Width, 13.5 feet; area, 13.1 square feet; mean velocity, 2.21 feet per second; gage height, 1.68 feet; discharge, 29 second-feet.

May 11: Width, 13.5 feet; area, 15 square feet; mean velocity, 2.33 feet per second; gage height, 1.80 feet; discharge, 35 second-feet.

*Butte Creek near Mount Hebron, Cal.*—Butte Creek rises on the eastern slope of Mount Shasta. It is tributary to Lower Klamath Lake and its waters sink in Butte Valley before reaching the lake. This creek discharges over fissured lava and large quantities of water are lost by seepage. That portion which reaches Butte Valley is used for irrigation. The following measurements were made during 1905 by C. T. Darley, 1½ miles above Boyce ranch at county road crossing.

May 5: Width, 15.5 feet; area, 51 square feet; mean velocity, 1.33 feet per second; gage height, 3.77 feet; discharge, 68 second-feet.

May 19: Width, 15.9 feet; area, 51 square feet; mean velocity, 1.47 feet per second; gage height, 3.95 feet; discharge, 75 second-feet.

June 16: Width, 16 feet; area, 48 square feet; mean velocity, 1.08 feet per second; gage height, 3.72 feet; discharge, 52 second-feet.

August 29: Width, 14 feet; area, 35 square feet; mean velocity, 0.47 foot per second; gage height, 3.00 feet; discharge, 16.4 second-feet.

November 23: Width, 14 feet; area, 36 square feet; mean velocity, 0.23 foot per second; gage height, 3.30 feet; discharge, 8.1 second-feet.

*Bowne's west canal, near Bonanza, Oreg.*—This canal takes water from Lost River, the water being raised by means of pumps and used for irrigation in the vicinity of Bonanza, Oreg. A measurement was made on May 31 by C. T. Darley at a point 300 feet below head of flume.

Width, 9.5 feet; area, 5.9 square feet; mean velocity, 1.46 feet per second; discharge, 8.6 second-feet.

*Boards ditch, Poe Valley, Oreg.*—This ditch diverts water from Lost River. The water is raised by means of a water wheel and is used for irrigation in the vicinity of Olene, Oreg. A measurement was made on July 19 by C. T. Darley at a point 300 feet below head of canal.

Width, 2 feet; area, 1.56 square feet; mean velocity, 0.22 foot per second; discharge, 0.3 second-foot.

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*Coyote Creek, Oreg.*—Coyote Creek is tributary to Sycan marsh. During 1905 discharge measurements were made by Ivan Landes as follows:

March 15: Width, 5.5 feet; area, 4.7 square feet; mean velocity, 0.89 foot per second; discharge, 4.2 second-feet.

April 10: Width, 6.0 feet; area, 6.1 square feet; mean velocity, 1.34 feet per second; discharge, 8.2 second-feet.

May 2: Width, 6.0 feet; area, 5.6 square feet; mean velocity, 1.05 feet per second; discharge, 5.9 second-feet.

June 12: Width, 5.0 feet; area, 3.4 square feet; mean velocity, 0.50 foot per second; discharge, 1.7 second-feet.

July 31: Width, 1.4 feet; area, 0.4 square foot; mean velocity, 1.38 feet per second; discharge, 0.6 second-foot.

*Crooked Creek near Klamath Agency, Oreg.*—This stream is a tributary of Wood River. A measurement was made May 27 by C. T. Darley at the bridge 1½ miles from Klamath Agency, on road to Fort Klamath.

Width, 24.8 feet; area, 88 square feet; mean velocity, 0.52 foot per second; discharge, 46 second-feet.

*Cherry Creek near Crystal, Oreg.*—This stream is tributary to Upper Klamath Lake from the west. A measurement was made on May 25 by C. T. Darley at road crossing between Pelican Bay and Fort Klamath.

Width, 27 feet; area, 25 square feet; mean velocity, 1.28 feet per second; discharge, 32 second-feet.

*Crane Creek near Fort Klamath, Oreg.*—Crane Creek is a tributary to Seven Mile Creek. A measurement was made on May 25 by C. T. Darley at the bridge on wagon road between Fort Klamath and Pelican Bay, Oreg.

Width, 11.5 feet; area, 20 square feet; mean velocity, 0.54 foot per second; discharge, 10.7 second-feet.

*Cottonwood Creek near Brownell, Cal.*—Cottonwood Creek is tributary to Lower Klamath Lake from the South. The following measurements were made during 1905, 1 mile below its source, at "F" ranch, Brownell:

June 15: Width, 19.5 feet; area, 41 square feet; mean velocity, 0.25 foot per second; discharge, 10.2 second-feet.

August 30: Width, 27.5 feet; area, 24 square feet; mean velocity, 0.53 foot per second; discharge, 12.6 second-feet.

*Doris Creek near Picard, Cal.*—Doris Creek is tributary to Lower Klamath Lake from the southwest. A measurement was made on June 18 by C. T. Darley at the Doris ranch.

Width, 5.4 feet; area, 4.9 square feet; mean velocity, 1.24 feet per second; discharge, 6.1 second-feet.

*Dirty Creek, Oregon.*—Dirty Creek is tributary to Sycan marsh. During 1905 discharge measurements were made by Ivan Landes, as follows:

March 15: Width, 3.0 feet; area, 1.4 square feet; mean velocity, 0.98 foot per second; discharge, 1.4 second-feet.

April 10: Width, 3.0 feet; area, 1.5 square feet; mean velocity, 0.99 foot per second; discharge, 1.3 second-feet.

May 2: Width, 3.0 feet; area, 1.4 square feet; mean velocity, 1.0 foot per second; discharge, 1.4 second-feet.

*Edson Foulks ditch.*—This ditch is in Shasta Valley. A measurement was made at head of ditch September 3, 1905, by L. G. Applegate.

Width, 6.3 feet; area, 6.3 square feet; mean velocity, 1.75 feet per second; discharge, 11 second-feet.

*Four Mile Creek, Pelican Bay, Oregon.*—Four Mile Creek is tributary to Upper Klamath Lake from the west. Its source is in Four Mile Lake. A measurement was made May 24 by C. T. Darley at road crossing between Klamath Falls and Pelican Bay.

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Width, 50.5 feet; area, 75 square feet; mean velocity, 0.70 foot per second; discharge, 53 second-feet.

*Grass Valley Creek near Lowden, Cal.*—Grass Valley Creek is tributary to Trinity River. A measurement was made of this stream August 26, 1905, by W. B. Clapp at lower wagon bridge on Buckhorn road 2½ miles above junction of creek with Trinity River.

Width, 19 feet; area, 18.7 square feet; mean velocity, 0.98 foot per second; discharge, 18.4 second-feet.

*Griffith canal near Olene, Oreg.*—This canal diverts water from Lost River. The water is raised by means of a water wheel and used for irrigation of land in the vicinity of Olene. The following measurements were made during 1905 by C. T. Darley at head of canal:

June 2: Width, 2 feet; area, 1.4 square feet; mean velocity, 1.29 feet per second; discharge, 1.8 second-feet.

June 13: Width, 2 feet; area, 1.5 square feet; mean velocity, 1.27 feet per second; discharge, 1.9 second-feet.

June 25: Width, 2 feet; area, 1.16 square feet; mean velocity, 1.08 feet per second; discharge, 1.3 second-feet.

*Hot Springs Creek near Klamath Falls, Oreg.*—Hot Springs Creek rises about one-half mile east of Klamath Falls and discharges into Lower Klamath Lake. A measurement was made on August 18 by C. T. Darley near point where creek crosses county road east of Klamath Falls, Oreg.

Width, 1.5 feet; area, 0.36 square foot; mean velocity, 0.94 foot per second; discharge, 4.4 second-feet.

*Horton ditch at Poe Valley, Oreg.*—This ditch diverts water from Lost River, which is used for irrigation on the south side of the river. A measurement was made on June 23 by C. T. Darley at a point one-fourth of a mile below head of ditch.

Width, 7.5 feet; area, 7.4 square feet; mean velocity, 0.59 foot per second; discharge, 4.4 second-feet.

*Little Shasta River at Little Shasta, Cal.*—A measurement of this stream was made August 29, 1905, by M. D. Williams.

Width, 9 feet; area, 5.4 square feet; mean velocity, 0.70 foot per second; discharge, 3.8 second-feet.

*Little Shasta Springs at Little Shasta, Cal.*—A measurement was made August 29, 1905, by M. D. Williams.

Width, 9 feet; area, 5.6 square feet; mean velocity, 3.57 feet per second; discharge, 20 second-feet.

*Long Creek, Oreg.*—Long Creek is tributary to Sycan Marsh. During 1905 discharge measurements were made by Ivan Landes as follows:

March 15: Width, 22 feet; area, 21.8 square feet; mean velocity, 1.54 feet per second; discharge, 33.6 second-feet.

April 10: Width, 25 feet; area, 36.9 square feet; mean velocity, 1.48 feet per second; discharge, 54.6 second-feet.

May 1: Width, 26 feet; area, 46.8 square feet; mean velocity, 1.45 feet per second; discharge, 68.1 second-feet.

June 12: Width, 25 feet; area, 37.6 square feet; mean velocity, 1.56 feet per second; discharge, 58.6 second-feet.

July 31: Width, 20 feet; area, 10.8 square feet; mean velocity, 1.72 feet per second; discharge, 18.6 second-feet.

*Moss Creek near Pelican Bay, Oregon.*—Moss Creek is tributary to Upper Klamath Lake from the west. A measurement was made on May 23 by C. T. Darley at road crossing between Pelican Bay and Klamath Falls, Oreg.

Width, 5.5 feet; area, 3.3 square feet; mean velocity, 0.76 foot per second; discharge, 2.5 second-feet.

*McCormick mill-race canal near Keno, Oreg.*—This canal diverts water from Klamath River about 1 mile below Keno, Oreg. This water is used for power purposes in running a

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sawmill. The following measurements were made during 1905 by C. T. Darley at a point one-fourth of a mile below head of canal:

June 19: Width, 17 feet; area, 43 square feet; mean velocity, 1.51 feet per second; discharge, 64 second-feet.

August 31: Width, 14.5 feet; area, 25 square feet; mean velocity, 2.12 feet per second; discharge, 53 second-feet.

*Moore's power canal near Klamath Falls, Oreg.*—This canal diverts water from the head of Link River and is used for power purposes in running a sawmill. The following measurement was made by C. T. Darley at a point one-half mile below head of canal:

March 25: Width, 9.9 feet; area, 34 square feet; mean velocity, 3.03 feet per second; discharge, 103 second-feet.

At a point 200 feet above Penstock the following measurements were made:

March 25: Width, 9 feet; area, 35 square feet; mean velocity, 2.14 feet per second; discharge, 75 second-feet.

June 21: Width, 9.5 feet; area, 34 square feet; mean velocity, 1.74 feet per second; discharge, 59 second-feet.

June 21: Width, 9.5 feet; area, 34 square feet; mean velocity, 1.56 feet per second; discharge, 53 second-feet.

*Moore's irrigation canal near Klamath Falls, Oreg.*—This canal diverts water from the head of Link River at same point at which water is diverted for Moore's mill-race canal on the west bank. This water is used for power purposes in running sawmill and the irrigation of town lots in the west addition of Klamath Falls, Oreg. The following measurements were made during 1905 by C. T. Darley at a point 300 feet below head of canal. These measurements show total amount of water used for power and irrigation purposes in this canal.

March 25: Width, 10 feet; area, 15.8 square feet; mean velocity, 0.82 foot per second; discharge, 12.9 second-feet.

June 21: Width, 12.4 feet; area, 10.1 square feet; mean velocity, 1.08 feet per second; discharge, 10.9 second-feet.

*Phillip's wheel canal near Spring Lake, Oregon.*—This canal diverts water from Lost River about 9 miles above Merrill, Oreg. The water is raised from the river by means of a water wheel and is used for irrigation purposes. The following measurements were made during 1905 by C. T. Darley at a point in flume 100 feet below point of diversion.

June 13: Width, 3 feet; area, 1.2 square feet; mean velocity, 1.00 foot per second; discharge, 1.2 second-feet.

July 25: Width, 1.2 feet; area, 0.1 square foot; discharge, 0.2 second-foot.

*Rock Creek near Aspin Lake, Oregon.*—This portion of Rock Creek is tributary to Upper Klamath Lake and has its source in Aspin Lake. A measurement was made on May 23 by C. T. Darley at bridge on wagon road between Klamath Falls and Pelican Bay.

Width, 23.5 feet; area, 16.9 square feet; mean velocity, 0.57 foot per second; discharge, 9.6 second-feet.

*Rock Creek at Crystal, Oreg.*—This stream is tributary to Crystal Creek and is a separate stream from the Rock Creek which discharges from Aspin Lake. A measurement was made on May 24 by C. T. Darley at bridge on wagon road between Klamath Falls and Pelican Bay.

Width, 19 feet; area, 8.9 square feet; mean velocity, 0.66 foot per second; discharge, 5.9 second-feet.

*Scott River near Fort Jones, Cal.*—Scott River is tributary to Klamath River. A measurement of this stream was made August 29, 1905, by W. B. Clapp 500 feet above wagon bridge on main road from Fort Jones to Etna, about 1 mile west from Fort Jones.

Width, 27 feet; area, 23 square feet; mean velocity, 1.17 feet per second; discharge, 27 second-feet.

*Seven Mile Creek near Fort Klamath, Oreg.*—This creek is tributary to Upper Klamath Lake from the north. A measurement was made on May 25 by C. T. Darley at bridge on wagon road between Fort Klamath and Pelican Bay.

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Width, 33 feet; area, 129 square feet; mean velocity, 0.79 foot per second; discharge, 102 second-feet.

*Shasta River near Yreka, Cal.*—Shasta River is tributary to Klamath River. A measurement of this stream was made August 29, 1905, by W. B. Clapp 5 miles northeast of Yreka and 500 feet below diversion dam of the Yreka Light and Power Company.

Width, 11.5 feet; area, 8.2 square feet; mean velocity, 1.22 feet per second; discharge, 10 second-feet.

There was on this date 107 second-feet being diverted into canal 500 feet above this point, giving a total discharge of 117 second-feet for this stream.

*Sheepy Creek near Brownell, Cal.*—This creek is tributary to Lower Klamath Lake from the southwest. The following measurements were made during 1905 by C. T. Darley at a point 2 miles east of Doris ranch, at wagon bridge near rock ford:

May 18: Width, 78 feet; area, 226 square feet; mean velocity, 0.12 foot per second; discharge, 27 second-feet.

June 18: Width, 80 feet; area, 218 square feet; mean velocity, 0.12 foot per second; discharge, 27 second-feet.

*Sprague River near Yainax, Oreg.*—Sprague River is tributary to Williamson River. A measurement was made on February 22 by C. T. Darley at bridge 5 miles below Yainax Agency. The gage is a 2 by 8 inch plank graduated to feet and tenths and nailed in a vertical position on the downstream side of the second bent from the south end of the bridge. The bench mark is a 2 by 4 inch stake driven flush with the ground on left bank of the stream in line with upstream side of the bridge and distant 74 feet from end of bridge. The zero of the gage is 21.9 feet below the bench mark.

Width, 133.2 feet; area, 1,077 square feet; mean velocity, 0.55 foot per second; discharge, 589 second-feet; gage height, 14.10 feet.

*Spring Creek near Fort Klamath, Oreg.*—This creek is tributary to Williamson River from the west. A measurement was made on August 13 by J. B. Lippincott and W. B. Clapp at a point 200 feet above its junction with Williamson River.

Width, 110 feet; area, 195 square feet; mean velocity, 1.86 feet per second; discharge, 362 second-feet.

*Swingle flume canal near Lorella, Oreg.*—This canal diverts water from Miller Creek above Lorella Bridge. The water is used for irrigation purposes in the vicinity of Lorella. A measurement was made on June 2 by C. T. Darley in small flume at road crossing on Langell Valley and Lorella road.

Width, 2 feet; area, 1.0 square foot; mean velocity, 0.20 foot per second; discharge, 0.2 second-foot.

*Three Mile Creek near Fort Klamath, Oreg.*—This creek is tributary to Upper Klamath Lake from the northwest. A measurement was made on May 25 by C. T. Darley at crossing of wagon road between Fort Klamath and Pelican Bay.

Width, 13.2 feet; area, 6.2 square feet; mean velocity, 1.00 foot per second; discharge, 6.2 second-feet.

*Trinity River near Lowden, Cal.*—Trinity River is tributary to Klamath River. A measurement of this stream was made August 26, 1905, by W. B. Clapp from a temporary pontoon bridge 1 mile above Lowden's ranch post-office and 3 miles below Lewiston, Cal. A permanent county highway bridge was being constructed at this point.

Width, 190 feet; area, 468 square feet; mean velocity, 0.50 foot per second; discharge, 233 second-feet.

*Varney Creek near Pelican Bay, Oregon.*—Varney Creek is tributary to Four Mile Creek. A measurement was made May 24 by C. T. Darley at road crossing between Pelican Bay and Klamath Falls.

Width, 9 feet; area, 13 square feet; mean velocity, 0.70 foot per second; discharge, 9.1 second-feet.

*Van Brimmer ditch, south branch, station No. 1, near Merrill, Oreg.*—This canal diverts water from White Lake, an arm of Lower Klamath Lake. For the first mile this canal is

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common with the Adams canal. This water is used for irrigation in the vicinity of Merrill, Oreg. The following measurements were made on this branch by C. T. Darley during 1905 at point 1 mile below the head of canal and at a point 300 feet below where Adams and Van Brimmer canals become separate and distinct. The gage rod is a 1 by 4 inch inclined timber graduated to feet and hundredths and nailed to posts set firmly in the bank of the canal. There is no bench mark.

May 14: Width, 20 feet; area, 23 square feet; mean velocity, 1.04 feet per second; gage, 4.01 feet; discharge, 24 second-feet.

May 21: Width, 18 feet; area, 17.2 square feet; mean velocity, 1.22 feet per second; gage, 3.78 feet; discharge, 21 second-feet.

June 14: Width, 18.6 feet; area, 16 square feet; mean velocity, 1.28 feet per second; gage, 3.92 feet; discharge, 20 second-feet.

July 22: Width, 18.3 feet; area, 13.9 square feet; mean velocity, 0.83 foot per second; gage, 3.84 feet; discharge, 11.5 second-feet.

August 24: Width, 17.5 feet; area, 10.4 square feet; mean velocity, 0.72 foot per second; gage, 3.72 feet; discharge, 7.5 second-feet.

August 24: Width, 18.2 feet; area, 12.3 square feet; mean velocity, 0.80 foot per second; gage, 3.85 feet; discharge, 9.9 second-feet.

August 25: Width, 19.8 feet; area, 17.9 square feet; mean velocity, 0.91 foot per second; gage, 4.12 feet; discharge, 16.3 second-feet.

August 25: Width, 16.5 feet; area, 5.3 square feet; mean velocity, 0.49 foot per second; gage, 3.40 feet; discharge, 2.6 second-feet.

August 25: Width, 17.0 feet; area, 6.9 square feet; mean velocity, 0.62 foot per second; gage, 3.55 feet; discharge, 4.3 second-feet.

*Van Brimmer ditch, north branch, station No. 2, near Merrill, Oreg.*—This canal diverts water from White Lake, an arm of Lower Klamath Lake. For the first mile this canal is common with the Adams canal. The following measurements were made of this branch during 1905 by C. T. Darley at a point 1 mile below heading and 300 feet below where Adams and Van Brimmer canals become separate and distinct. The gage is a 1 by 4 inch timber graduated to tenths and half tenths. It is set firmly to posts driven in the ground on the right bank. There is no bench mark.

May 14: Width, 13.8 feet; area, 8 square feet; mean velocity, 0.75 foot per second; gage, 1.95 feet; discharge, 6 second-feet.

May 21: Width, 14.3 feet; area, 7.5 square feet; mean velocity, 0.83 foot per second; gage, 1.99 feet; discharge, 6.2 second-feet.

June 15: Width, 15.4 feet; area, 7.4 square feet; mean velocity, 1.03 feet per second; gage, 2.21 feet; discharge, 7.6 second-feet.

July 24: Width, 16.5 feet; area, 10.4 square feet; mean velocity, 0.93 foot per second; gage, 2.34 feet; discharge 9.7 second-feet.

July 24: Width, 16.5 feet; area, 10.2 square feet; mean velocity, 0.93 foot per second; gage, 2.34 feet; discharge, 9.5 second-feet.

August 24: Width, 15.5 feet; area, 5.6 square feet; mean velocity, 0.79 foot per second; gage, 2.20 feet; discharge, 4.6 second-feet.

*Willow Creek near Brownell, Cal.*—Willow Creek is tributary to Lower Klamath Lake from the south. The following measurements were made during 1905 at bridge on Merrill and Brownell road by C. T. Darley:

May 20: Width, 20 feet; area, 17.2 square feet; mean velocity, 0.72 foot per second; discharge, 12.3 second-feet.

June 15 Width, 35.5 feet; area, 24 square feet; mean velocity, 0.48 foot per second; discharge, 11.5 second-feet.

August 30: Width, 18 feet; area, 13.9 square feet; mean velocity, 0.70 foot per second; discharge, 9.7 second-feet.

November 23: Width, 10 feet; area, 12.6 square feet; mean velocity, 0.87 foot per second; discharge, 11 second-feet.

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*Williamson River near Klamath Agency, Oreg.*—This stream is tributary to Upper Klamath Lake from the north. The following measurements were made during 1905 at bridge on county road between Klamath Falls and Fort Klamath, Oreg.:

May 27: Width, 175.8 feet; area, 1,532 square feet; mean velocity, 0.89 foot per second; discharge, 1,371 second-feet.

August 22: Width, 176 feet; area, 1,479 square feet; mean velocity, 0.58 foot per second; discharge, 858 second-feet.

At Chillaquin Bridge on road between Klamath Agency and Yainax Agency, November 14: Width, 40 feet; area, 230 square feet; mean velocity, 2.72 feet per second; discharge, 625 second-feet.

*Wood River near Fort Klamath, Oreg.*—Wood River is tributary to Upper Klamath Lake from the north. The following measurements were made during 1905 by C. T. Darley at bridge on county road, 4 miles below Fort Klamath, Oreg.:

May 27: Width, 52.3 feet; area, 297 square feet; mean velocity, 1.54 feet per second; discharge, 458 second-feet.

At bridge one-fourth mile below Fort Klamath, Oreg.:

August 22: Width, 47.6 feet; area, 166 square feet; mean velocity, 1.60 feet per second; discharge, 266 second-feet.

November 14: Width, 49 feet; area, 162 square feet; mean velocity, 1.59 feet per second; discharge, 259 second-feet.

December 10: Width, 49 feet; area, 162 square feet; mean velocity, 1.69 feet per second; discharge, 274 second-feet.

*Yreka Light and Power Company's canal near Yreka, Cal.*—A measurement of this canal was made August 29, 1905, by W. B. Clapp from footbridge at house 500 feet below concrete diversion dam at head of canal and distant about 5 miles northeast from Yreka. This canal diverts water from Shasta River.

Width, 17.5 feet; area, 36 square feet; mean velocity, 2.97 feet per second; discharge, 107 second-feet.

For total flow of Shasta River see measurement made same date below diversion dam.

## ROGUE RIVER DRAINAGE BASIN.

### ROGUE RIVER AT GOLD RAY, OREG.

This station was established August 30, 1905, by L. R. Allen. It is located at Gold Ray, Oreg., 1½ miles below Tolo post-office, just below the Condor Water and Power Company's dam and bridge, and a short distance below the mouth of Stewart Creek.

The channel is straight for 400 feet above and 300 feet below the station. The current at the measuring section is uniform. Both banks are high and rocky and are covered with a light growth of brush. The bed of the stream is rocky, somewhat broken in places, free from vegetation, and permanent. There is but one channel at all stages.

Discharge measurements are made by means of a cable, car, tagged wire, and stay line. The initial point is a tag on the tagged wire, 6.2 feet from the cable support on the left bank.

The gage is a vertical staff bolted to concrete pier of bridge about 300 feet above the cable. During 1905 the gage heights were furnished by the Condor Water and Power Company, observations being taken twice each day by C. E. Wertz. The bench mark is the top of the anchor bolt for stay line on the right bank. This bolt is well wedged in solid rock; elevation, 21.34 feet above the datum of the gage.



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*Discharge measurements of Rogue River at Gold Ray, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| August 30 | L. R. Allen | 180 | 1,013 | 1.29 | 1.10 | 1,307 |
| October 17 | do | 180 | 1,023 | 1.18 | 1.20 | 1,210 |
| December 26 | do | 184 | 1,100 | 1.38 | 1.57 | 1,514 |

*Daily gage height, in feet, of Rogue River at Gold Ray, Oreg., for 1905.*

| Day. | Sept. | Oct. | Nov. | Dec. | Day. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.1 | 1.2 | 1.2 | 1.32 | 17 | 1.2 | 1.25 | 1.22 | 1.32 |
| 2 | 1.1 | 1.17 | 1.2 | 1.3 | 18 | 1.1 | 1.25 | 1.3 | 1.4 |
| 3 | 1.1 | 1.15 | 1.2 | 1.3 | 19 | 1.1 | 1.25 | 1.3 | 1.45 |
| 4 | 1.15 | 1.15 | 1.2 | 1.27 | 20 | 1.05 | 1.25 | 1.5 | 1.47 |
| 5 | 1.15 | 1.17 | 1.2 | 1.45 | 21 | 1.05 | 1.25 | 1.3 | 1.4 |
| 6 | 1.12 | 1.3 | 1.2 | 1.32 | 22 | 1.1 | 1.25 | 1.25 | 1.35 |
| 7 | 1.1 | 1.45 | 1.2 | 1.35 | 23 | 1.1 | 1.2 | 1.25 | 1.17 |
| 8 | 1.1 | 1.6 | 1.2 | 1.35 | 24 | 1.1 | 1.2 | 1.22 | 1.25 |
| 9 | 1.1 | 1.35 | 1.2 | 1.3 | 25 | 1.15 | 1.2 | 1.2 | 1.32 |
| 10 | 1.6 | 1.25 | 1.2 | 1.3 | 26 | 1.15 | 1.37 | 1.2 | 1.6 |
| 11 | 1.1 | 1.2 | 1.2 | 1.2 | 27 | 1.17 | 1.35 | 1.3 | 1.82 |
| 12 | 1.15 | 1.2 | 1.2 | 1.2 | 28 | 1.3 | 1.3 | 1.3 | 1.65 |
| 13 | 1.15 | 1.2 | 1.2 | 1.2 | 29 | 1.2 | 1.35 | 1.4 | 1.5 |
| 14 | 1.15 | 1.17 | 1.2 | 1.3 | 30 | 1.2 | 1.3 | 1.3 | 1.6 |
| 15 | 1.1 | 1.2 | 1.2 | 1.3 | 31 | ..... | 1.22 | ..... | 1.52 |
| 16 | 1.1 | 1.22 | 1.2 | 1.32 | | | | | |

## UMPQUA RIVER DRAINAGE BASIN.

### SOUTH FORK OF UMPQUA RIVER NEAR BROCKWAY, OREG.

This station was established December 6, 1905, by L. R. Allen. It is located just below Winston's highway bridge, 3 miles east of Brockway, Oreg., and 3 miles below the mouth of Lookingglass Creek.

The channel is straight for 700 feet above and below the station. The current is uniform, somewhat broken by riffles at low water. Both banks are high, covered with brush, and not liable to overflow. The bed of the stream is of sand and gravel, free from vegetation, and shifting. There is but one channel at all stages.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is a tin tag on the top of the cable support at the right bank.

The gage is a staff in two sections. The lower section is inclined; the upper section is vertical. During 1905 the gage was read once each day by George Brosi. The bench mark is the top of square-headed iron bolt driven into the downstream end of sill of the bridge at the left bank; elevation, 23.31 feet above the datum of the gage.

*Discharge measurements of South Fork of Umpqua River near Brockway, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| December 28 | L. R. Allen | 302 | 1,616 | 1.85 | 4.16 | 2,998 |

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*Daily gage height, in feet, of South Fork of Umpqua River near Brockway, Oreg., for 1905.*

| Day. | Dec. | Day. | Dec. | Day. | Dec. | Day. | Dec. | Day. | Dec. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | 8 | 2.3 | 15 | 1.1 | 22 | 2.65 | 29 | 3.4 |
| 2 | | 9 | 2.1 | 16 | 1.05 | 23 | 2.2 | 30 | 4.35 |
| 3 | | 10 | 1.4 | 17 | 1.05 | 24 | 1.85 | 31 | 6.1 |
| 4 | | 11 | 1.4 | 18 | 1.1 | 25 | 1.1 | | |
| 5 | | 12 | 1.35 | 19 | 1.45 | 26 | 2.65 | | |
| 6 | 1.9 | 13 | 1.2 | 20 | 3.65 | 27 | 4.4 | | |
| 7 | 1.9 | 14 | 1.15 | 21 | 3.3 | 28 | 4.1 | | |

### NORTH FORK OF UMPQUA RIVER NEAR OAKCREEK, OREG.

This station was established September 6, 1905, by L. R. Allen. It is located 3 miles west of Oakcreek, Oreg., 1¼ miles above J. R. Dixon's farmhouse, about 10 miles below the mouth of East Fork of North Fork of Umpqua River.

The channel is straight for a half mile above and below the station. The current is swift. The right bank is low, covered with brush, and liable to overflow during floods. The left bank is similar, but somewhat higher, and not as apt to overflow. The bed of the stream is of gravel and rock, somewhat broken, free from vegetation, and shifting during floods. There is but one channel at all stages. Measurements may be affected by uncertainties of soundings due to the irregularities of the bed of the stream.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is a tag on the tagged wire, 2 feet from the cable support on the right bank.

Two gage rods were installed—one at the place of measurement and the other about 1 mile below. The lower portion of both rods is inclined, and the upper portion is vertical. During 1905 the gage was read once each day by Ethel Dixon. The bench mark at the lower gage is on top of a ¾-inch bolt, driven into sand rock about 50 feet east and 50 feet south of the gage; elevation, 28.47 feet above the datum of the gage.

*Discharge measurements of North Fork of Umpqua River near Oakcreek, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| September 6 | L. R. Allen | 215 | 457 | 1.94 | 1.35 | 886 |
| October 19 | do | 222 | 580 | 2.45 | 2.10 | 1,419 |
| December 27 | do | 279 | 1,447 | 4.91 | 5.35 | 7,110 |

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*Daily gage height, in feet, of North Fork of Umpqua River near Oakcreek, Oreg., for 1906.*

| Day. | Sept. | Oct. | Nov. | Dec. | Day. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.6 | 1.6 | 2.6 | 17 | 1.3 | 2.0 | 1.45 | 2.6 |
| 2 | ..... | 1.5 | 1.6 | 3.3 | 18 | 1.3 | 2.2 | 1.75 | 2.4 |
| 3 | ..... | 1.4 | 1.55 | 3.35 | 19 | 1.35 | 2.1 | 1.9 | 2.6 |
| 4 | ..... | 1.4 | 1.5 | 3.7 | 20 | 1.35 | 1.8 | 2.8 | 2.7 |
| 5 | ..... | 1.4 | 1.5 | 3.3 | 21 | 1.35 | 1.65 | 2.2 | 3.1 |
| 6 | 1.35 | 1.8 | 1.45 | 3.1 | 22 | 1.35 | 1.7 | 1.95 | 2.8 |
| 7 | 1.35 | 2.3 | 1.45 | 3.35 | 23 | 1.35 | 1.65 | 1.8 | 2.5 |
| 8 | 1.35 | 2.85 | 1.45 | 3.9 | 24 | 1.3 | 1.6 | 1.75 | 2.4 |
| 9 | 1.3 | 2.1 | 1.45 | 3.1 | 25 | 1.35 | 1.75 | 1.65 | 2.35 |
| 10 | 1.35 | 1.75 | 1.4 | 3.75 | 26 | 1.4 | 2.75 | 1.8 | 6.25 |
| 11 | 1.3 | 1.65 | 1.4 | 2.6 | 27 | 1.5 | 2.3 | 2.7 | 5.35 |
| 12 | 1.3 | 1.55 | 1.4 | 2.55 | 28 | 1.65 | 2.0 | 2.2 | 4.35 |
| 13 | 1.3 | 1.5 | 1.4 | 2.5 | 29 | 1.6 | 1.8 | 2.2 | 3.6 |
| 14 | 1.3 | 1.45 | 1.4 | 2.4 | 30 | 1.5 | 1.7 | 2.7 | 4.5 |
| 15 | 1.3 | 1.65 | 1.4 | 2.35 | 31 | ..... | 1.6 | ..... | 4.3 |
| 16 | 1.3 | 2.5 | 1.35 | 2.3 | | | | | |

## SILETZ RIVER DRAINAGE BASIN.

### SILETZ RIVER AT SILETZ, OREG.

This station was established November 25, 1905, by L. R. Allen. It is located at Siletz, Oreg., about 1 mile above the ferry on the Siletz and Toledo stage road, 6 miles below the mouth of Rock Creek.

The channel is straight for about 1,000 feet above and 400 feet below the station. The current is swift and rough. Both banks are high and not liable to overflow. The right bank is covered with brush; the left bank is timbered. The bed of the stream is of coarse gravel and sand, free from vegetation, and shifting. There is but one channel at all stages.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is a tin tag on the tagged wire, about 4 feet from the lower end of the turn-buckle on the right bank.

The gage is in two sections on the right bank. The lower section is inclined; the upper is vertical. During 1905 the gage was read once each day by John Kentta. The bench mark is the top of the head of a bolt driven into a large alder tree on the right bank, about 100 feet above the cable; elevation, 18.48 feet above the datum of the gage.

*Discharge measurements of Siletz River at Siletz, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Sq. ft.* | *Ft. per sec.* | *Feet.* | *Sec.-ft.* |
| November 26 | L. R. Allen | 157 | 394 | 2.95 | 2.15 | 1,167 |

*Daily gage height, in feet, of Siletz River at Siletz, Oreg., for 1905.*

| Day. | Nov. | Dec. | Day. | Nov. | Dec. | Day. | Nov. | Dec. | Day. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 3.75 | 9 | ..... | 2.9 | 17 | ..... | 7.8 | 25 | ..... | 3.2 |
| 2 | ..... | 4.2 | 10 | ..... | 2.6 | 18 | ..... | 6.0 | 26 | 2.1 | 7.5 |
| 3 | ..... | 3.8 | 11 | ..... | 2.5 | 19 | ..... | 5.3 | 27 | 2.0 | 5.2 |
| 4 | ..... | 3.3 | 12 | ..... | 2.3 | 20 | ..... | 5.6 | 28 | 2.0 | 4.3 |
| 5 | ..... | 3.0 | 13 | ..... | 2.2 | 21 | ..... | 4.9 | 29 | 2.7 | 3.8 |
| 6 | ..... | 3.7 | 14 | ..... | 2.1 | 22 | ..... | 4.0 | 30 | 3.2 | 4.3 |
| 7 | ..... | 3.3 | 15 | ..... | 2.0 | 23 | ..... | 3.9 | 31 | ..... | 5.7 |
| 8 | ..... | 3.1 | 16 | ..... | 2.2 | 24 | ..... | 3.1 | | | |

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# INDEX.


A.

Page.

Acknowledgments and cooperation ..... 12
Acre-foot, definition of ..... 4
Adams ditch near—
  Merrill, Oreg.:
    description ..... 242
    discharge ..... 242
Adin, Cal.
  Ash Creek at:
    description ..... 144
    discharge ..... 145
    discharge, monthly ..... 147
    gage heights ..... 146
    rating table ..... 146
  Rush Creek near:
    description ..... 152
    discharge ..... 152
  Willow Creek near:
    description ..... 152
    discharge ..... 152
Alamitos canal at—
  Calexico, Cal.:
    discharge ..... 31
    discharge, monthly ..... 32
    gage heights ..... 31, 32
Alamo channel near—
  Rockwood, Cal.:
    discharge ..... 80
    gage heights ..... 80
Alturas, Cal.
  E. Lauer & Son's ditch near:
    description ..... 151
    discharge ..... 151
  Fitz Hugh Creek near:
    description ..... 151
    discharge ..... 151
  Pine Creek near:
    description ..... 151
    discharge ..... 152
Alvord, Cal.
  Sanger canal at:
    description ..... 70
    discharge ..... 71
    gage heights ..... 71
American River near—
  Fairoaks, Cal.:
    description ..... 176
    discharge ..... 176
    discharge, monthly ..... 178
    gage heights ..... 177
    rating table ..... 177, 178
American River, North and Middle forks, near—
  Auburn, Cal.:
    description ..... 179
    discharge ..... 179

Page.

American River, Silver and South forks, near—
  Slippery Ford, Cal.:
    description ..... 179
    discharge ..... 179
American River, South Fork, near—
  Placerville, Cal.:
    description ..... 178
    discharge ..... 178
American River basin:
  description ..... 175–176
  miscellaneous measurements ..... 178–179
Ankeny ditch and canal near—
  Klamath Falls, Oreg.:
    description ..... 243
    discharge ..... 243
Antelope Creek near—
  Mount Hebron, Cal.:
    description ..... 242
    discharge ..... 242
  Red Bluff, Cal.:
    description ..... 132
    discharge ..... 132
Arrowhead Springs, Cal.
  East Twin Creek near:
    description ..... 103
    discharge ..... 103
  Waterman Canyon (West Twin Creek) near:
    description ..... 104
    discharge ..... 104
Arroyo Seco near—
  Pasadena, Cal.:
    description ..... 109
    discharge ..... 109
  Soledad, Cal.:
    description ..... 123–124
    discharge ..... 124
    discharge, monthly ..... 126
    gage heights ..... 125
    rating table ..... 125
Ash Creek at and near—
  Adin, Cal.:
    description ..... 144
    discharge ..... 145
    discharge, monthly ..... 147
    gage heights ..... 146
    rating table ..... 146
  Lone Pine, Cal.:
    description ..... 84
    discharge ..... 84
Aspin Lake, Oreg.
  Rock Creek near:
    description ..... 246
    discharge ..... 246


Digitized by Google

Auburn, Cal. Page.
American River, North and Middle forks, near:
description ..... 179
discharge..... 179
Azusa, Cal.
San Gabriel River and canals near:
description ..... 104
discharge..... 105, 107
discharge, monthly ..... 107
gage heights..... 105
rating table ..... 106

B.

Baird Station, Cal.
Sacramento, River at:
description ..... 131
discharge..... 131
Bakersfield, Cal.
Kearn River near:
description ..... 187
discharge..... 188
discharge, monthly ..... 189
Baldwin ditch near—
El Monte, Cal.:
description ..... 108
discharge..... 108
Balls Ferry, Cal.
Battle Creek near:
description ..... 132
discharge..... 132
Mill ditch near:
description ..... 132
discharge..... 132
Banta ditch near—
Los Nietos, Cal.:
description ..... 108
discharge..... 108
Battle Creek near—
Balls Ferry, Cal.:
description ..... 132
discharge..... 132
Bay Counties Power Company flume near—
Nevada City, Cal.:
description ..... 164
discharge..... 164
Bear Creek, California:
description ..... 200
discharge..... 200
Bear River above and near—
Wheatland, Cal.:
description ..... 165
discharge..... 166
discharge, monthly ..... 167
gage heights..... 166
rating table ..... 167
Colfax, Cal.:
description ..... 168
discharge..... 168
Bear River basin:
description ..... 165
miscellaneous measurements ..... 168
Beaver Creek, California:
description ..... 222
discharge..... 222

Beckwith, Cal. Page.
Grizzly Creek near:
description ..... 159
discharge..... 159
Bieber, Cal.
Pit River near:
description ..... 136
discharge..... 137
discharge, monthly ..... 138
gage heights ..... 136
rating table ..... 138
Big Creek, California:
description ..... 185
discharge..... 186
Big Pine, Cal.
Big Pine Creek near:
description ..... 78
discharge..... 79
discharge, monthly ..... 80
gage heights..... 79
rating table ..... 80
Clear Creek near:
description ..... 84
discharge..... 84
Fish Springs near:
description ..... 85
discharge..... 85
Big Pine and Owens River canal near—
Bishop, Cal.:
description ..... 69
discharge..... 69
gage heights ..... 70
Big Pine Creek near—
Big Pine, Cal.:
description ..... 78
discharge..... 79
discharge, monthly ..... 80
gage heights..... 79
rating table ..... 80
Big Tejunga Creek near—
Sunland, Cal.:
description ..... 109
discharge..... 109
Birch Creek near—
Bishop, Cal.:
description ..... 84
discharge..... 84
Tinemaha, Cal.:
description ..... 80
discharge..... 81
gage heights ..... 81
Bishop, Cal.
A. O. Collins canal near:
description ..... 66
discharge..... 67
gage heights ..... 67
Big Pine and Owens River canal near:
description ..... 69
discharge..... 69
gage heights ..... 70
Birch Creek near:
description ..... 84
discharge..... 84
Bishop Creek near:
description ..... 62
discharge..... 63


Digitized by Google

Bishop, Cal.—Continued. Page.
Bishop Creeek near—Continued.
discharge, monthly ..... 65
gage heights..... 63, 64
rating table..... 64
Bishop Creek canal near:
description ..... 58
discharge..... 59
gage heights..... 59
Dell canal near:
description ..... 68
discharge..... 68
gage heights..... 68
Farmers' canal near:
description ..... 59
discharge..... 60
gage heights..... 60
George Collins canal near:
description ..... 61
discharge..... 62
gage heights..... 62
McGee Creek near:
description ..... 86
discharge..... 86
McNally canal near:
description ..... 61
discharge..... 61
gage heights..... 61
North Hillside canal near:
description ..... 78
discharge..... 78
gage heights..... 78
Owens River canal near:
description ..... 57
discharge..... 57
gage heights..... 57, 58
Powers canal near:
description ..... 76
discharge..... 77
gage heights..... 77
Rawson canal near:
description ..... 65
discharge..... 65
gage heights..... 65, 66
South Hillside canal near:
description ..... 77
discharge..... 77
gage heights..... 77
Bishop Creek near—
Bishop, Cal.:
description ..... 62
discharge..... 63
discharge, monthly..... 65
gage heights..... 63, 64
rating table..... 64
Bishop Creek canal near—
Bishop, Cal.:
description ..... 58
discharge..... 59
gage heights..... 59
Blue Canyon Creek, California:
description ..... 200
discharge..... 200
Boards ditch, Poe Valley, Oregon:
description ..... 243
discharge..... 243

Bonanza, Oreg. Page.
Bowne's west canal near:
description ..... 243
discharge..... 243
Boulder Creek, California:
description ..... 198
discharge..... 198
Boundary canal near—
Calexico, Cal.:
discharge..... 35
discharge, monthly ..... 35
gage heights..... 35
Bowne's west canal near—
Bonanza, Oreg.:
description ..... 243
discharge..... 243
Bridal Veil Creek in—
Yosemite Valley, California:
description ..... 209
discharge..... 209
Brockway, Oreg.
Umpqua River, South Fork, near:
description ..... 250
discharge..... 250
gage heights ..... 251
Brownell, Cal.
Cottonwood Creek near:
description ..... 244
discharge..... 244
Sheepy Creek near:
description ..... 247
discharge..... 247
Willow Creek near:
description ..... 248
discharge..... 248
Bubbs Creek, California:
description ..... 199
discharge..... 199
Butte Creek near—
Mount Hebron, Cal.:
description ..... 243
discharge..... 243


C.


Cable Canyon Creek near—
Glen Helen, Cal.:
description ..... 102
discharge..... 102
Cable station, figure showing ..... 8
Cache Creek at and near—
Lower Lake, Cal.:
description ..... 169
discharge..... 170
discharge, monthly ..... 172
gage heights..... 171
rating table..... 171
Yolo, Cal.:
description ..... 172
discharge..... 173
discharge, monthly ..... 174
gage heights..... 173
rating table ..... 174
Cache Creek basin:
description ..... 168
miscellaneous measurements ..... 178–179


Digitized by Google

Calabasas, Cal. Page.
Malibu Creek near:
description ..... 111
discharge..... 111
discharge, monthly ..... 113
gage heights..... 112
Triunfo Creek near:
description ..... 113
discharge..... 114
discharge, monthly ..... 115
gage heights..... 114
Calexico, Cal.
Alamitos canal at:
discharge..... 31
discharge, monthly ..... 32
gage heights..... 31, 32
Boundary canal near:
discharge..... 35
discharge, monthly ..... 35
gage heights..... 35
Hemlock canal near:
discharge..... 28
discharge, monthly ..... 29
gage heights..... 28, 29
Holt canal near:
discharge..... 26
discharge, monthly ..... 27
gage heights..... 26, 27
Main canal near:
discharge..... 33
discharge, monthly..... 34
gage heights..... 33, 34
New Holt canal near:
discharge, monthly ..... 28
New River near:
discharge..... 30
gage heights..... 30
Wisteria canal near:
discharge..... 36
discharge, monthly ..... 37
gage heights..... 36, 37
California, southern:
Miscellaneous measurements..... 126
California-Mexico Land and Cattle Company's flume near—
Mexicala, Cal.:
description ..... 41
discharge, monthly ..... 41
Calpella, Cal.:
Russian River at:
description ..... 225
discharge..... 225
Camulos, Cal.
Camulos ditch near:
description ..... 115
discharge..... 116
Santa Clara River near:
description ..... 117
discharge..... 117
Canals below Yuma, Ariz., measurements of..... 18-42
Canby, Cal.
Pit River near:
description ..... 134
discharge..... 134
discharge, monthly ..... 136
gage heights..... 135
rating table ..... 135

Capay ditch at— Page
Capay, Cal.:
description ..... 175
discharge..... 175
Cascade Creek in—
Yosemite Valley, California:
description ..... 209
discharge..... 209
Cate ditch near—
El Monte, Cal.:
description ..... 108
discharge..... 108
Centerville, Cal.
Valley Counties Power Company's canal near:
description ..... 133
discharge..... 133
Cherry Creek near—
Crystal, Oreg.:
description ..... 244
discharge..... 244
Cherry River, California:
description ..... 216
discharge..... 216
Chino Creek near—
Rincon, Cal.:
description ..... 102
discharge..... 102
Citrus, Cal.
East Side canal near:
description ..... 71
discharge..... 72
gage heights..... 72
Owens River near:
description ..... 74
discharge..... 75
discharge, monthly..... 76
gage heights..... 75
rating table..... 76
Stevens canal near:
description ..... 73
discharge..... 73
gage heights..... 74
City Creek near—
Highlands, Cal.:
description ..... 102
discharge..... 102
Clavey River, California:
description ..... 216
discharge..... 216
Clear Creek near—
Big Pine, Cal.:
description ..... 84
discharge..... 84
Stella, Cal.:
description ..... 131
discharge..... 131
Clear Lake at—
Lakeport, Cal.:
description ..... 168
evaporation ..... 169
Clear Lake, Cal.
Lost River near:
description ..... 233
discharge..... 233
discharge, monthly..... 235
gage heights..... 234
rating table ..... 234


Digitized by Google

Clements, Cal. Page.
Mokelumne River near:
description ..... 223
discharge..... 223
discharge, monthly..... 225
gage heights..... 224
rating table ..... 224
Clover Creek near—
Upper Lake, Cal.:
description ..... 175
discharge..... 175
Clover Creek and ditch at—
Millville, Cal.:
description ..... 132
discharge..... 132
Cole Creek at—
Kelseyville, Cal.:
description ..... 175
discharge..... 175
Colfax, Cal.
Bear River near:
description ..... 168
discharge..... 168
Green Horn River near:
description ..... 168
discharge..... 168
South Yuba Mining Company's ditch near:
description ..... 168
discharge..... 168
Collins, A. O., canal near—
Bishop, Cal.:
description ..... 66
discharge..... 67
gage heights ..... 67
Collins, George, canal near—
Bishop, Cal.:
description ..... 61
discharge..... 62
gage heights..... 62
Colorado River, diversion of, by Imperial Canal, measurement of..... 24
Colorado River at and below—
Yuma, Ariz.:
description ..... 13
discharge..... 14-16
discharge, monthly..... 16
gage heights..... 14, 15, 17
Heading No. 3 of Imperial Canal:
description ..... 17
discharge..... 18
gage heights..... 18
Colorado River basin:
miscellaneous measurements in..... 42
Colorado Valley Pumping and Irrigation Company's canal at—
Yuma, Ariz.:
description ..... 18
discharge..... 19
Computation, methods of..... 10-12
rules for ..... 4
Converse Creek, California:
description..... 198
discharge..... 198
Cooperation and acknowledgments..... 12
Copper City, Cal.
Pit River near:
description ..... 132
discharge..... 132

Copper City, Cal.—Continued. Page.
Squaw Creek near:
description ..... 132
discharge..... 132
Copper Creek, California:
description ..... 199
discharge..... 199
Corporation ditch near—
Likely, Cal.:
description ..... 151
discharge..... 151
Cottonwood Creek near—
Brownell, Cal.:
description ..... 244
discharge..... 244
Jamul, Cal.:
description ..... 126
discharge..... 126
gage height..... 126
Lakeview, Oreg.:
description ..... 151
discharge..... 151
Olancha, Cal.:
description ..... 85
discharge..... 85
gage heights..... 85
Cottonwood Creek, North and Middle forks, near—
Gas Point, Cal.:
description ..... 131, 132
discharge..... 131, 132
Covelo, Cal.
Middle Eel River at:
description ..... 226
discharge..... 226
Cow Creek at and near—
Millville, Cal.:
description ..... 132
discharge..... 132
Palocedro, Cal.:
description ..... 132
discharge..... 132
Coyote Creek, Oregon:
description ..... 244
discharge..... 244
Crane Creek near—
Fort Klamath, Oreg.:
description ..... 244
discharge..... 244
Crescent Mills, Cal.
Indian Creek near:
description ..... 159
discharge..... 159
Crooked Creek near—
Klamath Agency, Oreg.:
description ..... 244
discharge..... 244
Crown Creek, California:
description..... 200
discharge..... 200
Crystal, Oreg.
Cherry Creek near:
description ..... 244
discharge ..... 244
Rock Creek at:
description ..... 246
discharge..... 246
Current meters, classes of ..... 8
methods of using ..... 8-10


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Page.

Curves for area, discharge, and mean velocity, figure showing ..... 11

D.

Davis ditch near—
Downieville, Cal.:
description ..... 165
discharge ..... 165
Deer Creek near—
Vina, Cal.:
description ..... 133
discharge ..... 133
Dell canal near—
Bishop, Cal.:
description ..... 68
discharge ..... 68
gage heights ..... 68
Devil Canyon near—
Irvington Station, Cal.:
description ..... 102
discharge ..... 103
Dinkey Creek, California:
description ..... 200
discharge ..... 200
Dirty Creek, Oregon:
description ..... 244
discharge ..... 244
Division Creek near—
Independence, Cal.:
description ..... 85
discharge ..... 85
Doris Creek near—
Picard, Cal.:
description ..... 244
discharge ..... 244
Dougherty Creek, California:
description ..... 200
discharge ..... 200
Downieville, Cal.
Davis ditch near:
description ..... 165
discharge ..... 165
Wheeler flume near:
description ..... 164
discharge ..... 164
Yuba River, East Fork of North Fork, at:
description ..... 165
discharge ..... 165
Yuba River, Nork Fork, at:
description ..... 165
discharge ..... 165
Yuba River, North Fork of North Fork, at and near:
description ..... 164, 165
discharge ..... 164, 165
Drainage basins, list of ..... 2-3
Duke's ditch near—
Likely, Cal.:
description ..... 151
discharge ..... 151
Duty of water in Imperial Valley ..... 40

E.

East Highlands, Cal.
Plunge Creek near:
description ..... 103
discharge ..... 103
East Side canal near— Page.
Citrus, Cal.:
description ..... 71
discharge ..... 72
gage heights ..... 72
East Twin Creek near—
Arrowhead Springs, Cal.:
description ..... 103
discharge ..... 103
Edson Foulks ditch, Shasta Valley:
description ..... 244
discharge ..... 244
Eel River at—
Laytonville, Cal.:
description ..... 226
discharge ..... 226
Eel River basin:
miscellaneous measurements ..... 225-226
Eight Mile Creek near—
Independence, Cal.:
description ..... 85
discharge ..... 85
El Dorado ditch below—
Slippery Ford, Cal.:
description ..... 179
discharge ..... 179
El Monte, Cal.
Baldwin ditch near:
description ..... 108
discharge ..... 108
Cate ditch near:
description ..... 108
discharge ..... 108
Ranchito or Standerford ditch near:
description ..... 108
discharge ..... 108
Rincon ditch near:
description ..... 108
discharge ..... 108
Rio Hondo near:
description ..... 108
discharge ..... 108
San Gabriel River near:
description ..... 108
discharge ..... 108
Sheep Creek ditch near:
description ..... 108
discharge ..... 108
Eleanor Creek, California:
description ..... 216
discharge ..... 216
Equivalents, table of ..... 5-6
Esperanza, Cal.
Piru Land and Water Company's upper diversion near:
description ..... 116
discharge ..... 116

F.

Fairoaks, Cal.
American River near:
description ..... 176
discharge ..... 176
discharge, monthly ..... 178
gage heights ..... 177
rating table ..... 177, 178


Digitized by Google

Page.

Falls Creek, California:
description ..... 216
discharge ..... 216
Farmers' canal near—
Bishop, Cal.:
description ..... 59
discharge ..... 60
gage heights ..... 60
Santa Paula, Cal.:
description ..... 116
discharge ..... 116
Yuma, Ariz.:
description ..... 19
discharge ..... 19
Feather River at—
Oroville, Cal.:
description ..... 155–156
discharge ..... 156
discharge, monthly ..... 158
gage heights ..... 157
rating table ..... 158
Prattville, Cal.:
description ..... 159
discharge ..... 159
Feather River, Middle Fork, at—
Mohawk Valley, Cal.:
description ..... 159
discharge ..... 159
Feather River basin:
description ..... 155
miscellaneous measurements ..... 159
Fernando, Cal.
Pacoima Creek near:
description ..... 110
discharge ..... 110
Fish Creek, California:
description ..... 186
discharge ..... 186
Fish Springs near—
Big Pine, Cal.:
description ..... 85
discharge ..... 85
Fitz Hugh Creek near—
Alturas, Cal.:
description ..... 151
discharge ..... 151
Floats, use of, in measuring discharge ..... 7–8
Fort Klamath, Oreg.
Crane Creek near:
description ..... 244
discharge ..... 244
Seven-Mile Creek near:
description ..... 246
discharge ..... 247
Spring Creek near:
description ..... 247
discharge ..... 247
Three Mile Creek near:
description ..... 247
discharge ..... 247
Wood River near:
description ..... 249
discharge ..... 249
Fort Jones, Cal.
Scott River near:
description ..... 246
discharge ..... 246

Page.

Four Mile Creek, Pelican Bay, Oregon:
description ..... 244
discharge ..... 245
Fruto, Cal.
Stony Creek basin:
description ..... 153
discharge ..... 153
discharge, monthly ..... 155
gage heights ..... 154
rating table ..... 154

G.

Gaging stations, equipment of ..... 7–8
Ganstad's ditch near—
Likely, Cal.:
description ..... 151
discharge ..... 151
Gas Point, Cal.
Cottonwood Creek, North and Middle forks, near:
description ..... 131, 132
discharge ..... 131, 132
Georges Creek near—
Independence, Cal.—
description ..... 85
discharge ..... 85
Glen Helen, Cal.
Cable Canyon Creek near:
description ..... 102
discharge ..... 102
Goddard Creek, California:
description ..... 199
discharge ..... 200
Gold Ray, Oreg.
Rogue River at:
description ..... 249
discharge ..... 250
gage heights ..... 250
Gooch's ditch near—
Lookout, Cal.:
description ..... 151
discharge ..... 151
Goodale Creek near—
Tibbetts, Cal.:
description ..... 85
discharge ..... 85
Goodyears bar, California.
Yuba River, North Fork, near:
description ..... 164
discharge ..... 164
Granite Creek, California:
description ..... 199
discharge ..... 199
Grass Valley Creek near—
Lowden, Cal.:
description ..... 245
discharge ..... 245
Green Horn River near—
Colfax, Cal.:
description ..... 168
discharge ..... 168
Grees ditch near—
Santa Paula, Cal.:
description ..... 116
discharge ..... 116


Digitized by Google

Page.

Gregory, Cal.
McCloud River near:
description ..... 147
discharge ..... 148
discharge, monthly ..... 150
gage heights ..... 148
rating table ..... 149
Sacramento River at:
description ..... 131
discharge ..... 131
Griffith canal near—
Olene, Oreg.:
description ..... 245
discharge ..... 245
Griswald Creek, California:
description ..... 222
discharge ..... 222
Grizzly Creek near—
Beckwith, Cal.:
description ..... 159
discharge ..... 159
Guenoc, Cal.
Puta Creek near:
description ..... 180
discharge ..... 180
discharge, monthly ..... 182
gage heights ..... 181
rating table ..... 182

H.

Heading No. 3 of Imperial Canal.
Colorado River below:
description ..... 17
discharge ..... 18
gage heights ..... 18
Hearst, Cal.
South Eel River at:
description ..... 225
discharge ..... 225
Hemlock Canal near—
Calexico, Cal.:
discharge ..... 28
discharge, monthly ..... 29
gage heights ..... 28, 29
Herndon, Cal.
San Joaquin River at:
description ..... 184
gage heights ..... 185
Hetch Hetchy, Cal.
Tuolumne River at:
description ..... 216
discharge ..... 216
Highlands, Cal.
City Creek near:
description ..... 102
discharge ..... 102
Holt Canal near—
Calexico, Cal.:
discharge ..... 26
discharge, monthly ..... 27
gage heights ..... 26, 27
Home Camp Creek, California:
description ..... 185
discharge ..... 185
Horse Fly, near Lorella, Oreg., precipitation at ..... 242
Horseshoe Creek, California:
description ..... 199
discharge ..... 199

Page.

Horton ditch at—
Poe Valley, Oreg.:
description ..... 245
discharge ..... 245
Hot Springs Creek near—
Klamath Falls, Oreg.:
description ..... 245
discharge ..... 245
Hotel Creek, California:
description ..... 199
discharge ..... 199
Hydrographic surveys, annual appropriations for ..... 1
organization and scope of ..... 1-3

I.

Ice-covered streams, methods of measuring flow of ..... 10
Imperial, Cal.
McKim flume near:
description ..... 40
discharge, monthly ..... 41
rainfall records at ..... 41
Tamarack canal near:
discharge ..... 38
discharge, monthly ..... 38
gage heights ..... 38
Imperial canal below—
Quail River cut-off, Mexico:
discharge ..... 42
Imperial canal in—
United States and Mexico:
description ..... 20-23
discharge ..... 23, 24
discharge, monthly ..... 25
Imperial Valley:
duty of water in ..... 40
lands irrigated in ..... 40
soil of, tests of ..... 40, 41
Imperial Valley canals:
description ..... 25
discharge ..... 26, 28, 30, 31, 33, 35, 36, 38, 39
discharge, monthly ..... 27-29, 32, 34, 35, 37, 38
gage heights ..... 27, 29, 32, 34, 37, 38
Independence, Cal.
Division Creek near:
description ..... 85
discharge ..... 85
Eight Mile Creek near:
description ..... 85
discharge ..... 86
Georges Creek near:
description ..... 85
discharge ..... 85
Independence Creek near:
description ..... 81
discharge ..... 82
discharge, monthly ..... 83
gage heights ..... 82
rating table ..... 83
Moffett Creek near:
description ..... 86
discharge ..... 86
Oak Creek near:
description ..... 83
discharge ..... 83
gage heights ..... 84


Digitized by Google

Independence, Cal.—Continued. Page.
Shepherds Creek near:
description ..... 86
discharge..... 86
Independence Creek near—
Independence, Cal.:
description ..... 81
discharge..... 82
discharge, monthly..... 83
gage heights..... 82
rating table..... 83
Indian Creek near—
Crescent Mills, Cal.:
description ..... 159
discharge..... 159
Irrigation in Imperial Valley, amount of .. 40
Irvington Station, Cal.
Devil Canyon near:
description ..... 102
discharge..... 103
Ivy, Cal.
Pit River, South Fork, near:
description ..... 139
discharge..... 140

J.

Jamul, Cal.
Cottonwood Creek near:
description ..... 126
discharge..... 126
gage heights..... 126

K.

Kaweah River below—
Three Rivers, Cal.:
description ..... 192
discharge..... 193
discharge, monthly..... 194
gage heights..... 193
rating table..... 194
Kaweah River, East Fork, at—
Mount Whitney Power Company's power house, California:
description ..... 195
discharge..... 196
Kaweah River, Middle Fork, in—
Sequoia National Park, Cal.:
description ..... 194
discharge ..... 194
Kaweah River, North and South forks, near—
Three Rivers, Cal.:
description ..... 194, 195
discharge..... 194, 196
Kaweah River basin:
description ..... 192
miscellaneous measurements ..... 194–195
Kelsey Creek near—
Kelseyville, Cal.:
description ..... 175
discharge..... 175
Kelseyville, Cal.
Cole Creek at:
description ..... 175
discharge ..... 175
Keno, Oreg. Page.
McCormick mill-race canal near:
description ..... 245
discharge..... 246
Klamath River at:
description ..... 229
discharge..... 230
discharge, monthly ..... 231
gage heights..... 230
rating table ..... 231
precipitation..... 242
evaporation..... 242
Kern River near—
Bakersfield, Cal.:
description ..... 187
discharge..... 188
discharge, monthly ..... 189
Kern River basin:
description ..... 187
King Creek, California:
description ..... 186
discharge..... 186
Kings River near—
Sanger, Cal.:
description ..... 196
discharge..... 196
discharge, monthly ..... 198
gage heights..... 197
rating table ..... 197
Kings River, Middle, North, and South forks, California:
description ..... 198, 199, 200
discharge..... 198, 199, 200
Kings River basin:
description ..... 195
miscellaneous measurements ..... 198–200
Klamath Agency, Oreg.
Crooked Creek near:
description ..... 244
discharge..... 244
Williamson River near:
description ..... 249
discharge..... 249
Klamath Falls, Oreg.
Ankeny ditch and canal near:
description ..... 243
discharge..... 243
Hot Springs Creek near:
description ..... 245
discharge..... 245
Link River at:
description ..... 226
discharge..... 227
discharge, monthly ..... 229
gage heights..... 228
rating table ..... 228
Moore's irrigation and power canals near:
description ..... 246
discharge..... 246
Klamath River at—
Keno, Oreg.
description ..... 229
discharge..... 230
discharge, monthly ..... 231
gage heights..... 230
rating table ..... 231

Digitized by Google

Knights Ferry, Cal. Page.
Stanislaus River at:
description ..... 217–218
discharge..... 218
discharge, monthly ..... 220
gage heights..... 219
rating table ..... 219
Stanislaus Water Company's ditch at:
description ..... 220
discharge..... 221
gage heights..... 221
rating table ..... 222

L.

Lagrange, Cal.
Mining ditch near:
description ..... 217
discharge..... 217
Modesto canal at:
description ..... 212–213
discharge..... 213
gage heights..... 213
rating table ..... 214
Tuolumne River at:
description ..... 209–210
discharge..... 210
discharge, monthly ..... 212
gage heights..... 211
rating table ..... 212
Turlock canal at:
description ..... 214
discharge..... 214
gage heights..... 215
rating table ..... 215
Lakeside, Cal.
San Diego River near:
description ..... 126
discharge..... 127
Lakeview, Oreg.
Cottonwood Creek near:
description ..... 151
discharge..... 151
Lauer, E., & Son's ditch near—
Alturas, Cal.:
description ..... 151
discharge..... 151
Laurel Creek, California:
description ..... 200
discharge..... 200
Laytonville, Cal.
Eel, Middle Eel, and South Eel rivers at:
description ..... 226
discharge..... 226
Lewis Creek, California:
description ..... 198
discharge..... 198
Lightning Creek, California:
description ..... 198
discharge..... 198
Likely, Cal.
Corporation ditch near:
description ..... 151
discharge..... 151
Duke's ditch near:
description ..... 151
discharge..... 151

Likely, Cal.—Continued. Page.
Ganstad's ditch near:
description ..... 151
discharge..... 151
Van Loam's ditch near:
description ..... 152
discharge..... 152
West Valley Creek near:
description ..... 140
discharge..... 141, 143
discharge, monthly ..... 144
gage heights ..... 142
Link River at—
Klamath Falls, Oreg.:
description ..... 226
discharge..... 227
discharge, monthly ..... 229
gage heights ..... 228
rating table..... 228
Little Cow Creek near—
Palocedro, Cal.:
description ..... 132
discharge..... 132
Little Shasta River and Springs at—
Little Shasta, Cal.:
description ..... 245
discharge..... 245
Little Tejunga Creek near—
Sunland, Cal.:
description ..... 110
discharge..... 110
Lone Pine, Cal.
Ash Creek near:
description ..... 84
discharge..... 84
Lone Pine Creek near:
description ..... 85
discharge..... 85
Tuttle Creek near:
description ..... 86
discharge..... 86
Lone Pine Creek near—
Lone Pine, Cal.:
description ..... 85
discharge..... 85
Long Creek, Oregon:
description ..... 245
discharge..... 245
Lookout, Cal.
Gooch's ditch near:
description ..... 151
discharge..... 151
Lookout, Cal.
Pit River, at:
description ..... 152
discharge..... 152
Lorella, Oreg.
Miller Creek near:
description ..... 239
discharge..... 240
discharge, monthly ..... 241
gage heights ..... 240
rating table ..... 241
Swingle flume canal near:
description ..... 247
discharge..... 247
precipitation near..... 242


Digitized by Google

Los Angeles River, at— Page.
Los Angeles, Cal.:
description ..... 110
discharge ..... 110
Los Angeles River basin:
description ..... 109
miscellaneous measurements ..... 109–110
Los Nietos ditch near—
Los Nietos, Cal.:
description ..... 108
discharge ..... 108
Lost River near—
Clear Lake, Cal.:
description ..... 233
discharge ..... 233
discharge, monthly ..... 235
gage heights ..... 234
rating table ..... 234
Merrill, Oreg.:
description ..... 236
discharge ..... 236
discharge, monthly ..... 238
gage heights ..... 237
rating table ..... 237
Lowden, Cal.
Grass Valley Creek near:
description ..... 245
discharge ..... 245
Trinity River near:
description ..... 247
discharge ..... 247
Lower Lake, Cal.
Cache Creek at:
description ..... 169
discharge ..... 170
discharge, monthly ..... 172
gage heights ..... 171
rating table ..... 171
Ludy canal near—
Yuma, Ariz.:
description ..... 19–20
discharge ..... 20
gage heights ..... 20
Lytle Creek near—
Rialto, Cal.:
description ..... 103
discharge ..... 103

M.

McCloud River near—
Gregory, Cal.:
description ..... 147
discharge ..... 148
discharge, monthly ..... 150
gage heights ..... 148
rating table ..... 149
McCormick mill-race canal near—
Keno, Oreg.:
description ..... 245
discharge ..... 246
McGee Creek near—
Bishop, Cal.:
description ..... 86
discharge ..... 86
McKim flume near—
Imperial, Cal.:
description ..... 40
discharge, monthly ..... 41
McNally canal near— Page.
Bishop, Cal.:
description ..... 61
discharge ..... 61
gage heights ..... 61
Main canal near—
Calexico, Cal.:
discharge ..... 33
discharge, monthly ..... 34
gage heights ..... 33, 34
Malibu Creek near—
Calabasas, Cal.:
description ..... 111
discharge ..... 111
discharge, monthly ..... 113
gage heights ..... 112
Malibu Creek basin.
description ..... 111
Marble Fork in—
Sequoia National Park, Cal.:
description ..... 194
discharge ..... 194
Mentone, Cal.
Mill Creek near:
description ..... 103
discharge ..... 103
Morton Canyon Creek near:
description ..... 103
discharge ..... 103
Redlands tunnel near:
description ..... 103
discharge ..... 103
Santa Ana River near:
description ..... 94–95
discharge ..... 95, 98
discharge, monthly ..... 98
gage heights ..... 96
rating table ..... 96, 97
Merced Falls, Cal.
Merced River above:
description ..... 203
discharge ..... 203
discharge, monthly ..... 205
gage heights ..... 204
rating table ..... 204
Merced River in—
Yosemite Valley, California:
description ..... 201
discharge ..... 201
discharge, monthly ..... 203
gage heights ..... 202
rating table ..... 202
Merced River basin.
description ..... 200
miscellaneous measurements ..... 209
Merrill, Oreg.
Adams ditch near:
description ..... 242
discharge ..... 242
Lost River near:
description ..... 236
discharge ..... 236
discharge, monthly ..... 238
gage heights ..... 237
rating table ..... 237
Tule Lake near:
description ..... 238
gage heights ..... 239


Digitized by Google

Merrill, Oreg.—Continued. Page.
Van Brimmer ditch near:
description ..... 247, 248
discharge ..... 248
Merrillville, Cal.
Willow Creek at:
description ..... 45
discharge, monthly ..... 47
gage heights ..... 46
rating table ..... 46
Methods of computing run-off ..... 10–11
of measuring stream flow ..... 6–10
Mexicala, Cal.
California-Mexico Land and Cattle Company's flume near:
description ..... 41
discharge, monthly ..... 41
Middle Creek near—
Upper Lake, Cal.:
description ..... 175
discharge ..... 175
Middle Eel River at—
Covelo, Cal.:
description ..... 226
discharge ..... 226
Laytonville, Cal.:
description ..... 226
discharge ..... 226
Middle Fork, etc. *See name of river.*
Mill Creek near—
Mentone, Cal.:
description ..... 103
discharge ..... 103
Tehama, Cal.:
description ..... 132
discharge ..... 133
Mill ditch near—
Balls Ferry, Cal.:
description ..... 132
discharge ..... 132
Miller Creek near—
Lorella, Oreg.:
description ..... 239
discharge ..... 240
discharge, monthly ..... 241
gage heights ..... 240
rating table ..... 241
Millrace canal near—
Tehama, Cal.:
description ..... 133
discharge ..... 133
Millville, Cal.
Clover Creek and ditch at:
description ..... 132
discharge ..... 132
Cow Creek at:
description ..... 132
discharge ..... 132
Miner's inch, definition of ..... 3
Mining company's flume near—
Sierra City, Cal.:
description ..... 165
discharge ..... 165
Modesto canal at—
Lagrange, Cal.:
description ..... 212–213
discharge ..... 213
gage heights ..... 213
rating table ..... 214
Moffett Creek near— Page.
Independence, Cal.:
description ..... 86
discharge ..... 86
Mohave River at—
Victorville, Cal.:
description ..... 87
discharge ..... 88, 90
discharge, monthly ..... 90
gage heights ..... 89
Mohave River basin:
description ..... 87
Mohawk Creek near—
New Mohawk, Cal.:
description ..... 159
discharge ..... 159
Mohawk Valley, Cal.
Feather River, Middle Fork, at:
description ..... 159
discharge ..... 159
Mokelumne River near—
Clements, Cal.:
description ..... 223
discharge ..... 223
discharge, monthly ..... 225
gage heights ..... 224
rating table ..... 224
Mokelumne River basin:
description ..... 223
Mono Creek, California:
description ..... 186
discharge ..... 186
Moore's ditch near—
Woodland, Cal.:
description ..... 175
discharge ..... 175
Moore's irrigation and power canals near—
Klamath Falls, Oreg.:
description ..... 246
discharge ..... 246
Morton Canyon Creek near—
Mentone, Cal.:
description ..... 103
discharge ..... 103
Moss Creek near—
Pelican Bay, Oregon:
description ..... 245
discharge ..... 245
Mount Hebron, Cal.
Antelope Creek near:
description ..... 242
discharge ..... 242
Butte Creek near:
description ..... 243
discharge ..... 243
Mount Whitney Power Company's flume at—
Sequoia National Park, Cal.:
description ..... 195
discharge ..... 195
Mount Whitney Power Company's power house, California.
Kaweah River, East Fork, at:
description ..... 196
discharge ..... 195
Mugler Creek, California:
description ..... 186
discharge ..... 186
Multiple-point method of measuring discharge, description of ..... 9


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N.

Page.

Nevada City, Cal.
Bay Counties Power Company flume near:
description ..... 164
discharge ..... 164
Yuba River, Middle Fork, near:
description ..... 164
discharge ..... 164
New Holt canal near—
Calexico, Cal.:
discharge, monthly ..... 28
New Mohawk, Cal.
Mohawk Creek near:
description ..... 159
discharge ..... 159
New River near—
Calexico, Cal.:
discharge ..... 30
gage heights ..... 30
North Fork, etc. *See name of river.*
North Hillside canal near—
Bishop, Cal.:
description ..... 78
discharge ..... 78
gage heights ..... 78

O.

Oak Creek near—
Independence, Cal.:
description ..... 83
discharge ..... 83
gage heights ..... 84
Oakcreek, Oreg.
Umpqua River, North Fork, near:
description ..... 251
discharge ..... 251
gage heights ..... 252
Olancha, Cal.
Cottonwood Creek near:
description ..... 85
discharge ..... 85
gage heights ..... 85
Olene, Oreg.
Griffith Canal near:
description ..... 245
discharge ..... 245
Oroville, Cal.
Feather River at:
description ..... 155–156
discharge ..... 156
discharge, monthly ..... 158
gage heights ..... 157
rating table ..... 158
Owens River near—
Citrus, Cal.:
description ..... 74
discharge ..... 75
discharge, monthly ..... 76
gage heights ..... 75
rating table ..... 76
Round Valley, Cal.:
description ..... 50
discharge ..... 50
discharge, monthly ..... 52
gage heights ..... 51
rating table ..... 52
Owens River basin:
description ..... 49
miscellaneous measurements in ..... 84–86
Owens River Canal near—
Bishop, Cal.:
description ..... 57
discharge ..... 57
gage heights ..... 57, 58

P.

Pacific Ocean drainage, northern:
miscellaneous measurements ..... 242–249
Pacoima Creek near—
Fernando, Cal.:
description ..... 110
discharge ..... 110
Pala, Cal.
San Luis Rey River near:
description ..... 91
discharge ..... 92
discharge, monthly ..... 93
gage heights ..... 92
Palocedro, Cal.
Cow Creek near:
description ..... 132
discharge ..... 132
Little Cow Creek near:
description ..... 132
discharge ..... 132
Parrotts Ferry, Cal.
Stanislaus River at:
description ..... 222
discharge ..... 222
Pasadena, Cal.
Arroyo Seco, Cal.:
description ..... 109
discharge ..... 109
Pelican Bay, Oregon.
Moss Creek near:
description ..... 245
discharge ..... 245
Varney Creek near:
description ..... 247
discharge ..... 247
Phillip's wheel canal near—
Spring Lake, Oreg.
description ..... 246
discharge ..... 246
Picard, Cal.
Doris Creek near:
description ..... 244
discharge ..... 244
Pine Creek near—
Alturas, Cal.:
description ..... 151
discharge ..... 152
Round Valley, Cal.:
description ..... 55
discharge ..... 55
discharge, monthly ..... 57
gage heights ..... 56
rating table ..... 56
Piru City, Cal.
Piru Creek near:
description ..... 116
discharge ..... 117



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Piru Land and Water Company's upper diversion near— Page.
Esperanza, Cal.:
description ... 116
discharge ... 116
Pit River at and near—
Bieber, Cal.:
description ... 136
discharge ... 137
discharge, monthly ... 139
gage heights ... 138
rating table ... 138
Canby, Cal.:
description ... 134
discharge ... 134
discharge, monthly ... 136
gage heights ... 135
rating table ... 135
Copper City, Cal.:
description ... 132
discharge ... 132
Lookout, Cal.:
description ... 152
discharge ... 152
Pit River, South Fork, near—
Ivy, Cal.:
description ... 139
discharge ... 140
Pit River basin:
description ... 133
miscellaneous measurements ... 151-152
Pitman Creek, California:
description ... 185
discharge ... 185
Placerville, Cal.:
American River, South Fork, near—
description ... 178
discharge ... 178
Plunge Creek, near—
East Highlands, Cal.:
description ... 103
discharge ... 103
Poe Valley, Oreg.
Horton ditch at:
description ... 245
discharge ... 245
Portersville, Cal.
Tule River, near:
description ... 189
discharge ... 190
discharge, monthly ... 191
gage heights ... 190
rating table ... 191
Powers canal near—
Bishop, Cal.:
description ... 76
discharge ... 77
gage heights ... 77
Prattville, Cal.
Feather River at—
description ... 159
discharge ... 159
Preston, Cal.
Russian River at—
description ... 225
discharge ... 225
Puta Creek at and near— Page.
Guenoc, Cal.:
description ... 180
discharge ... 180
discharge, monthly ... 182
gage heights ... 181
rating table ... 182
Winters, Cal.:
description ... 182-183
discharge ... 183
gage heights ... 183
Puta Creek basin:
description ... 179

Q.

Quail River cut-off, Mexico.
Imperial canal below:
discharge ... 42

R.

Rainfall, record of, at—
Imperial, Cal ... 41
Keno, Lorella, and Tule Lake, Oreg ... 242
Rancheria Creek, California:
description ... 216
discharge ... 216
Rancheria Creek and North Fork, California:
description ... 200
discharge ... 200
Ranchito ditch near—
El Monte, Cal.:
description ... 106
discharge ... 108
Rating curves, methods of constructing ... 10-11
Rating tables, methods of constructing ... 10-11
Rawson canal near—
Bishop, Cal.:
description ... 65
discharge ... 65
gage heights ... 65, 66
Red Bluff, Cal.
Antelope Creek near:
description ... 132
discharge ... 132
Sacramento River near:
description ... 128
discharge ... 129
discharge, monthly ... 130
gage heights ... 129
rating table ... 130
Redlands, Cal.
Santa Ana River near:
description ... 103
discharge ... 103
Redlands tunnel near—
Mentone, Cal.:
description ... 103
discharge ... 103
Reds Creek, California:
description ... 186
discharge ... 186
Rialto, Cal.
Lytle Creek near:
description ... 103
discharge ... 103


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Ribbon Falls Creek in— Page.
Yosemite Valley, California:
description ..... 209
discharge ..... 209
Rincon, Cal.
Chino Creek near:
description ..... 102
discharge ..... 102
Santa Ana River near:
description ..... 103
discharge ..... 103
gage height ..... 103
Rincon ditch near—
El Monte, Cal.:
description ..... 108
discharge ..... 108
Rio Hondo near—
El Monte, Cal.:
description ..... 108
discharge ..... 108
Roaring River, California:
description ..... 199
discharge ..... 199
Rock Creek at and near—
Aspin Lake, Oregon:
description ..... 246
discharge ..... 246
Crystal, Oreg.:
description ..... 246
discharge ..... 246
Round Valley, Cal.:
description ..... 52
discharge ..... 53, 54
discharge, monthly ..... 54
gage heights ..... 53
Rockwood, Cal.
Alamo channel near:
discharge ..... 30
gage heights ..... 30
Rogue River, at—
Gold Ray, Oreg.:
description ..... 249
discharge ..... 250
gage heights ..... 250
Round Valley, Cal.
Pine Creek near:
description ..... 55
discharge ..... 55
discharge, monthly ..... 57
gage heights ..... 56
rating table ..... 56
Owens River near:
description ..... 50
discharge ..... 50
discharge, monthly ..... 52
gage heights ..... 51
rating table ..... 52
Rock Creek near:
description ..... 52
discharge ..... 53, 54
discharge, monthly ..... 54
gage heights ..... 53
Rules for computation ..... 4-5
Run-off, office methods of computing, in inches, definition of ..... 10-12
Rush Creek near— Page.
Adin, Cal.:
description ..... 152
discharge ..... 152
Russian River, East Fork, near—
Ukiah, Cal.:
description ..... 225
discharge ..... 225
Russian River basin:
miscellaneous measurements ..... 225

S.

Sacramento, Cal.
Sacramento River at:
gage heights ..... 131
Sacramento River at and near—
Gregory (Baird Station), Cal.:
description ..... 131
discharge ..... 131
Red Bluff, Cal.:
description ..... 128
discharge ..... 129
discharge, monthly ..... 130
gage heights ..... 129
rating table ..... 130
Sacramento, Cal.:
gage heights ..... 131
Sacramento River basin:
description ..... 127
miscellaneous measurements ..... 127
Salinas River basin:
description ..... 123
Salton sea, discharge into, amount of ..... 39
San Diego River near—
Lakeside, Cal.:
description ..... 126
discharge ..... 127
San Francisquito Creek near—
Saugus, Cal.:
description ..... 116
discharge ..... 116
San Gabriel River near—
El Monte, Cal.:
description ..... 108
discharge ..... 108
San Gabriel River and canals near—
Azusa, Cal.:
description ..... 104
discharge ..... 105, 107
discharge, monthly ..... 107
gage heights ..... 105
rating table ..... 106
San Gabriel River basin:
description ..... 104
miscellaneous measurements ..... 108
San Joaquin River:
description ..... 184
miscellaneous measurements ..... 185-187
San Joaquin River at—
Herndon, Cal.:
description ..... 184
gage heights ..... 185
San Joaquin power house, California:
description ..... 187
discharge ..... 187


Digitized by Google

San Joaquin River, Middle Fork, California: Page.
description 186
discharge 186
San Joaquin River, North Fork, California:
description 186
discharge 186
San Joaquin River, South Fork, California:
description 186
discharge 186
San Luis Rey River near—
Pala, Cal.:
description 91
discharge 92
discharge, monthly 93
gage heights 92
San Luis Rey River basin:
description 91
San Pasqual, Cal.
Santa Ysabel River near:
description 127
discharge 127
gage heights 127
Sanger, Cal.
Kings River near:
description 196
discharge 196
discharge, monthly 198
gage heights 197
rating table 197
Sanger canal at—
Alvord, Cal.:
description 70
discharge 71
gage heights 71
Santa Ana River, Cal.
Canals from:
discharge 102
Santa Ana River near—
Mentone, Cal.:
description 94–95
discharge 95, 98
discharge, monthly 98
gage heights 96
rating table 96, 97
Redlands, Cal.:
description 103
discharge 103
Rincon, Cal.:
description 103
discharge 103
gage heights 103
Santa Ana River basin:
description 94
miscellaneous measurements 102–104
seepage measurements 99
Santa Anita Creek near—
Sierra Madre, Cal.:
description 108
discharge 108
Santa Barbara, Cal.
Santa Ynez River near:
description 117–118
discharge, monthly 119
gage heights 118
rating table 119
Santa Clara River near— Page.
Camulos, Cal.:
description 117
discharge 117
Santa Paula, Cal.:
description 117
discharge 117
Saticoy, Cal.:
description 117
discharge 117
Saugus, Cal.:
description 117
discharge 117
Santa Clara River basin:
description 115
miscellaneous measurements 115–117
Santa Clara Water and Irrigation Company's canal near—
Saticoy, Cal.:
description 117
discharge 117
Santa Maria, Cal.
Santa Maria River near:
description 120
discharge 121
discharge, monthly 123
gage heights 121
rating table 122
Santa Maria River basin:
description 120
Santa Paula, Cal.
Farmers' canal near:
description 116
discharge 116
Grees ditch near:
description 116
discharge 116
Santa Clara River near:
description 117
discharge 117
Santa Paula Creek near:
description 116
discharge 116
Santa Ynez River near—
Santa Barbara, Cal.:
description 117, 118
discharge, monthly 119
gage heights 118
rating table 119
Santa Ynez River basin:
description 117
Santa Ysabel River near—
San Pasqual, Cal.:
description 127
discharge 127
gage heights 127
Saticoy, Cal.
Santa Clara River near:
description 117
discharge 117
Santa Clara Water and Irrigation Company's canal near:
description 117
discharge 117


Digitized by Google

Saugus, Cal. Page.
San Francisquito Creek near:
description ..... 116
discharge ..... 116
Santa Clara River near:
description ..... 117
discharge ..... 117
Scott River near—
Fort Jones, Cal.:
description ..... 246
discharge ..... 246
Second-foot, definition of ..... 3
Seepage measurements:
Santa Ana River ..... 99
San Bernardino Valley ..... 101
Sequoia National Park, Cal.
Kaweah River, Middle Fork, in:
description ..... 194
discharge ..... 194
Marble Fork in:
description ..... 194
discharge ..... 194
Mount Whitney Power Company's flume at:
description ..... 195
discharge ..... 195
Sespe Creek near—
Sespe, Cal.:
description ..... 116
discharge ..... 116
Sespe Land and Water Company's canal near—
Sespe, Cal.:
description ..... 116
discharge ..... 116
Seven Mile Creek near—
Fort Klamath, Oreg.:
description ..... 246
discharge ..... 247
Shasta River near—
Yreka, Cal.:
description ..... 247
discharge ..... 247
Sheep Creek, California:
description ..... 199
discharge ..... 199
Sheep Creek ditch near—
El Monte, Cal.:
description ..... 108
discharge ..... 108
Sheepy Creek near—
Brownell, Cal.:
description ..... 247
discharge ..... 247
Shepherds Creek near—
Independence, Cal.:
description ..... 86
discharge ..... 86
Sierra City, Cal.
Mining Company's flume near:
description ..... 165
discharge ..... 165
Yuba River, North Fork of North Fork, near:
description ..... 165
discharge ..... 165
Sierra City, Cal.—Continued. Page.
Yuba River, South Fork of North Fork, near:
description ..... 165
discharge ..... 165
Sierra Madre, Cal.
Santa Anita Creek, near:
description ..... 108
discharge ..... 108
Siletz River at—
Siletz, Oreg.:
description ..... 252
discharge ..... 252
gage heights ..... 252
Silver Creek and South Fork, California:
description ..... 179
discharge ..... 179
Silverlake, Oreg.
Sycan River near:
description ..... 232
discharge ..... 232
gage heights ..... 232
Single-point method of measuring discharge, description of ..... 9
Slide Creek, California:
description ..... 200
discharge ..... 200
Slippery Ford, Cal.
American River, Silver and South Forks, near:
description ..... 179
discharge ..... 179
El Dorado ditch below:
description ..... 179
discharge ..... 179
Slope method of measuring discharge, use and value of ..... 6
Small Creek, California:
description ..... 186
discharge ..... 186
Smartville, Cal.
Yuba River, near:
description ..... 160
discharge ..... 161, 163
discharge, monthly ..... 164
gage heights ..... 162
Soil, classification and test of, in Imperial Valley ..... 40, 41
Soledad, Cal.
Arroyo Seco near:
description ..... 123–124
discharge ..... 124
discharge, monthly ..... 126
gage heights ..... 125
rating table ..... 125
South Eel River at—
Hearst, Cal.:
description ..... 225
discharge ..... 225
Laytonville, Cal.:
description ..... 226
discharge ..... 226
South Fork, etc. *See name of river.*
South Hillside canal near—
Bishop, Cal.:
description ..... 77
discharge ..... 77
gage heights ..... 77


Digitized by Google

South Yuba Mining Company's ditch near— Page.
Colfax, Cal,:
description ... 168
discharge ... 168
Sprague River near—
Yainax, Oreg.:
description ... 247
discharge ... 247
Spring Creek near—
Fort Klamath, Oreg.:
description ... 247
discharge ... 247
Spring Lake, Oreg.
Phillip's wheel canal near:
description ... 246
discharge ... 246
Springville, Cal.
Tule River, North and Middle forks, near:
description ... 191, 192
discharge ... 191, 192
Squaw Creek near—
Copper City, Cal.:
description ... 132
discharge ... 132
Squaw Hollow, Cal.
Stanislaus River at:
description ... 222
discharge ... 222
Standerford ditch near—
El Monte, Cal.:
description ... 108
discharge ... 108
Standish, Cal.
Willow Creek near:
description ... 47
discharge ... 47
discharge, monthly ... 49
gage heights ... 48
rating table ... 48
Stanislaus River at—
Knights Ferry, Cal.:
description ... 217–218
discharge ... 218
discharge, monthly ... 220
gage heights ... 219
rating table ... 219
Parrotts Ferry, Cal.:
description ... 222
discharge ... 222
Stanislaus River, North, Middle, and South forks, Cal.
description ... 222
discharge ... 222
Stanislaus River basin:
description ... 217
miscellaneous measurements ... 222
Stanislaus Water Company's ditch at—
Knights Ferry, Cal.:
description ... 220
discharge ... 221
gage heights ... 221
rating table ... 222
Stations, river, location of, map showing ... 2

Stella, Cal. Page.
Clear Creek near:
description ... 131
discharge ... 131
Stevens canal near—
Citrus, Cal.:
description ... 73
discharge ... 73
gage heights ... 74
Stevenson Creek, Cal.
description ... 186
discharge ... 186
Stony Creek near—
Fruto, Cal.:
description ... 153
discharge ... 153
discharge, monthly ... 155
gage heights ... 154
rating table ... 154
Stony Creek basin:
description ... 152
Stream flow, field methods of measuring ... 6–10
Success, Cal.
Tule River, South Fork, near:
description ... 191
discharge ... 191
Sunland, Cal.
Big Tejunga Creek near:
description ... 109
discharge ... 109
Little Tejunga Creek near:
description ... 110
discharge ... 110
Susan River near—
Susanville, Cal.:
description ... 42–43
discharge ... 43
discharge, monthly ... 45
gage heights ... 44
rating table ... 44
Susan River basin:
description ... 42
Susanville, Cal.
Susan River near:
description ... 42–43
discharge ... 43
discharge, monthly ... 45
gage heights ... 44
rating table ... 44
Sweetwater River near—
Descanso, Cal.:
description ... 127
discharge ... 127
gage heights ... 127
Swingle flume canal near—
Lorella, Oreg.:
description ... 247
discharge ... 247
Sycan River near—
Silverlake, Oreg.:
description ... 232
discharge ... 232
gage heights ... 232


Digitized by Google

T.

Page.

Tables, explanation of ..... 4
Taboose Creek near—
Tibbetts, Cal.:
description ..... 86
discharge ..... 86
Tamarack canal near—
Imperial, Cal.:
discharge ..... 38
discharge, monthly ..... 38
gage heights ..... 38
Tehama, Cal.
Mill Creek near:
description ..... 132
discharge ..... 133
Millrace canal near:
description ..... 133
discharge ..... 133
Temecula Creek near—
Temecula, Cal.:
description ..... 126
discharge ..... 126
gage heights ..... 126
Tenaya Creek in—
Yosemite Valley, California:
description ..... 207
discharge ..... 207
discharge, monthly ..... 208
gage heights ..... 208
rating table ..... 208
Ten Mile Creek, California:
description ..... 198
discharge ..... 198
Three Mile Creek near—
Fort Klamath, Oreg.:
description ..... 247
discharge ..... 247
Three Rivers, Cal.
Kaweah River below:
description ..... 192
discharge ..... 193
discharge, monthly ..... 194
gage heights ..... 193
rating table ..... 194
Kaweah River, North and South forks, near:
description ..... 194, 195
discharge ..... 194, 195
Tibbetts, Cal.
Goodale Creek near:
description ..... 85
discharge ..... 85
Taboose Creek near:
description ..... 86
discharge ..... 86
gage heights ..... 86
Tiltill Creek, California:
description ..... 216
discharge ..... 216
Tinemaha, Cal.
Tinemaha Creek near:
description ..... 86
discharge ..... 86
Birch Creek near:
description ..... 80
discharge ..... 81
gage heights ..... 81
Trinity River near—
Lowden, Cal.:
description ..... 247
discharge ..... 247
Triunfo Creek near—
Calabasas, Cal.:
description ..... 113
discharge ..... 114
discharge, monthly ..... 115
gage heights ..... 114
Tule Lake, California:
precipitation ..... 242
Tule Lake near—
Merrill, Oreg.:
description ..... 238
gage heights ..... 239
Tule River near—
Portersville, Cal.:
description ..... 189
discharge ..... 190
discharge, monthly ..... 191
gage heights ..... 190
rating table ..... 191
Tule River, North and Middle forks, near—
Springville, Cal.:
description ..... 191, 192
discharge ..... 191, 192
Tule River, South Fork, near—
Success, Cal.:
description ..... 191
discharge ..... 191
Tule River basin:
description ..... 189
miscellaneous measurements ..... 191–192
Tuolumne River at—
Hetch Hetchy, Cal.:
description ..... 216
discharge ..... 216
Lagrange, Cal.:
description ..... 209–210
discharge ..... 210
discharge, monthly ..... 212
gage heights ..... 211
rating table ..... 212
Tuolumne River, Middle and South forks, California:
description ..... 216, 217
discharge ..... 216, 217
Tuolumne River basin:
description ..... 209
miscellaneous measurements ..... 216–217
Turlock canal at—
Lagrange, Cal.:
description ..... 214
discharge ..... 214
gage heights ..... 215
rating table ..... 215
Tuttle Creek near—
Lone Pine, Cal.:
description ..... 86
discharge ..... 86

U.

Ukiah, Cal.
Russian River, East Fork, near:
description ..... 225
discharge ..... 225

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Page.

Umpqua River, North Fork, near—
Oakcreek, Oreg.:
description ..... 251
discharge ..... 251
gage heights ..... 252
Umpqua River, South Fork, near—
Brockway, Oreg.:
description ..... 250
discharge ..... 250
gage heights ..... 251
Upper Lake, Cal.
Clover Creek near:
description ..... 175
discharge ..... 175
Middle Creek near:
description ..... 175
discharge ..... 175

V.

Valley Counties Power Company's canal near—
Centerville, Cal.:
description ..... 133
discharge ..... 133
Van Brimmer ditch near—
Merrill, Oreg.:
description ..... 247, 248
discharge ..... 248
Van Loam's ditch near—
Likely, Cal.:
description ..... 152
discharge ..... 152
Varney Creek near—
Pelican Bay, Oregon:
description ..... 247
discharge ..... 247
Velocity method of measuring discharge, description of ..... 7–10
Vertical integration method of measuring discharge, description of ..... 9
Vertical velocity-curve method of measuring discharge, description of ... 9
Victorville, Cal.
Mohave River at:
description ..... 87
discharge ..... 88, 90
discharge, monthly ..... 90
gage heights ..... 89
Vina, Cal.
Deer Creek near:
description ..... 133
discharge ..... 133

W.

Waterman Canyon Creek near—
Arrowhead Springs, Cal.:
description ..... 104
discharge ..... 104
Weir method of measuring discharge, requirements of ..... 7
West Twin Creek near—
Arrowhead Springs, Cal.:
description ..... 104
discharge ..... 104

Page.

West Valley Creek near—
Likely, Cal.:
description ..... 140
discharge ..... 141, 143
discharge, monthly ..... 144
gage heights ..... 142
Wheatland, Cal.
Bear River above:
description ..... 165
discharge ..... 166
discharge, monthly ..... 167
gage heights ..... 166
rating table ..... 167
Wheeler flume near—
Downieville, Cal.:
description ..... 164
discharge ..... 164
Williamson River near—
Klamath Agency, Oreg.:
description ..... 249
discharge ..... 249
Willow Creek at and near—
Adin, Cal.:
description ..... 152
discharge ..... 152
Brownell, Cal.:
description ..... 248
discharge ..... 248
Merrillville, Cal.:
description ..... 45
discharge, monthly ..... 47
gage heights ..... 46
rating table ..... 46
Standish, Cal.:
description ..... 47
discharge ..... 47
discharge, monthly ..... 49
gage heights ..... 48
rating table ..... 48
Willow Creek, North Fork, California:
description ..... 187
discharge ..... 187
Winters, Cal.
Puta Creek at:
description ..... 182–183
discharge ..... 183
gage heights ..... 183
Wisteria canal near—
Calexico, Cal.:
discharge ..... 36
discharge, monthly ..... 37
gage heights ..... 36, 37
Wood River near—
Fort Klamath, Oreg.:
description ..... 249
discharge ..... 249
Woodland, Cal.
Moore's ditch near:
description ..... 175
discharge ..... 175

Y.

Yainax, Oreg.
Sprague River near:
description ..... 247
discharge ..... 247


Digitized by Google

Yolo, Cal. Page.
Cache Creek near:
description ..... 172
discharge ..... 173
discharge, monthly ..... 174
gage heights ..... 173
rating table ..... 174
Yosemite Creek in—
Yosemite Valley, California:
description ..... 205
discharge ..... 205
discharge, monthly ..... 207
gage heights ..... 206
rating table ..... 206
Yosemite Valley, California.
Bridal Veil Creek in:
description ..... 209
discharge ..... 209
Cascade Creek in:
description ..... 209
discharge ..... 209
Merced River in:
description ..... 201
discharge ..... 201
discharge, monthly ..... 203
gage heights ..... 202
rating table ..... 202
Ribbon Falls Creek in:
description ..... 209
discharge ..... 209
Tenaya Creek in:
description ..... 207
discharge ..... 207
discharge, monthly ..... 208
gage heights ..... 208
rating table ..... 208
Yosemite Creek in:
description ..... 205
discharge ..... 205
discharge, monthly ..... 207
gage heights ..... 206
rating table ..... 206
Yreka, Cal.
Shasta River near:
description ..... 247
discharge ..... 247
Yreka Light and Power Company's canal near:
description ..... 249
discharge ..... 249
Yuba River, near—
Smartsville, Cal.:
description ..... 160
discharge ..... 161, 163
Yuba River, near—Continued. Page.
Smartsville, Cal.—Continued.
discharge, monthly ..... 164
gage heights ..... 162
Yuba River, East Fork of North Fork, at—
Downieville, Cal.:
description ..... 165
discharge ..... 165
Yuba River, Middle Fork, near—
Nevada City, Cal.:
description ..... 164
discharge ..... 164
Yuba River, North Fork, at and near—
Downieville, Cal.:
description ..... 165
discharge ..... 165
Goodyears bar, California:
description ..... 164
discharge ..... 164
Yuba River, North Fork of North Fork, at and near—
Downieville, Cal.:
description ..... 164, 165
discharge ..... 164, 165
Sierra City, Cal.:
description ..... 165
discharge ..... 165
Yuba River, South Fork of North Fork, near—
Sierra City, Cal.:
description ..... 165
discharge ..... 165
Yuba River basin:
description ..... 159–160
miscellaneous measurements ..... 164–165
Yuma, Ariz., canals below, measurements of ..... 18–42
Colorado River at:
description ..... 18
discharge ..... 14–16
discharge, monthly ..... 16
gage heights ..... 14, 15, 17
Colorado Valley Pumping and Irrigation Company's canal at:
description ..... 18
discharge ..... 19
Farmers' canal near:
description ..... 19
discharge ..... 19
Ludy canal near:
description ..... 19–20
discharge ..... 20
gage heights ..... 20


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[Water-Supply Paper No. 177.]

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1888. Tenth Annual Report, Part II.
1889. Eleventh Annual Report, Part II.
1890. Twelfth Annual Report, Part II.
1891. Thirteenth Annual Report, Part III.
1892. Fourteenth Annual Report, Part II.
1893. Bulletin No. 131.
1894. Bulletin No. 131; Sixteenth Annual Report, Part II.
1895. Bulletin No. 140.
1896. Water-Supply Paper No. 11; Eighteenth Annual Report, Part IV.
1897. Water-Supply Papers Nos. 15 and 16; Nineteenth Annual Report, Part IV.
1898. Water-Supply Papers Nos. 27 and 28; Twentieth Annual Report, Part IV.
1899. Water-Supply Papers Nos. 35, 36, 37, 38, and 39; Twenty-first Annual Report, Part IV.
1900. Water-Supply Papers Nos. 47, 48, 49, 50, 51, and 52; Twenty-second Annual Report, Part IV.
1901. East of Mississippi River, Water-Supply Papers Nos. 65 and 75.
West of Mississippi River, Water-Supply Papers Nos. 66 and 75.

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1902. East of Mississippi River, Water-Supply Papers Nos. 82 and 83.
West of Mississippi River, Water-Supply Papers Nos. 84 and 85.
1903. East of Mississippi River, Water-Supply Papers Nos. 97 and 98.
West of Mississippi River, Water-Supply Papers Nos. 99 and 100.
1904. East of Mississippi River, Water-Supply Papers, Nos. 124, 125, 126, 127, 128, and 129.
West of Mississippi River, Water-Supply Papers Nos. 130, 131, 132, 133, 134, and 135.
1905. East of Mississippi River, Water-Supply Papers Nos. 165, 166, 167, 168, 169, 170, and 171.
West of Mississippi River, Water-Supply Papers Nos. 171, 172, 173, 174, 175, 176, 177, and 178.

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Water-Supply and Irrigation Paper No. 178 Series P, Hydrographic Progress Reports, 54

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

# REPORT

OF

# PROGRESS OF STREAM MEASUREMENTS

FOR

# THE CALENDAR YEAR 1905

PREPARED UNDER THE DIRECTION OF F. H. NEWELL

PART XIV.—Columbia River and Puget Sound Drainages

BY

D. W. ROSS, J. T. WHISTLER, and T. A. NOBLE

WASHINGTON
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# CONTENTS.


| | Page. |
|---|---|
| Introduction | 1 |
| Organization and scope of work | 1 |
| Definitions | 3 |
| Explanation of tables | 4 |
| Convenient equivalents | 5 |
| Field methods of measuring stream flow | 6 |
| Office methods of computing run-off | 10 |
| Cooperation and acknowledgments | 11 |
| Columbia River drainage basin | 12 |
| Description of basin | 12 |
| Columbia River near Julia, Wash | 12 |
| Columbia River near Pasco, Wash | 13 |
| Clark Fork drainage basin | 14 |
| Description of basin | 14 |
| Clark Fork at Priest River, Idaho | 15 |
| Missoula River at Missoula, Mont | 16 |
| Big Blackfoot River near Bonner, Mont | 19 |
| Bitterroot River near Grantsdale, Mont | 21 |
| Priest River at Priest River, Idaho | 23 |
| Spokane River drainage basin | 24 |
| Description of basin | 24 |
| Cœur d'Alene Lake at Cœur d'Alene, Idaho | 24 |
| Spokane River at Spokane, Wash | 25 |
| Hangman Creek at Tekoa, Wash | 27 |
| Hangman Creek at Poole's ranch, near Tekoa, Wash | 29 |
| North Fork of Hangman Creek at Tekoa, Wash | 29 |
| Little Spokane River near Spokane, Wash | 31 |
| Okanogan River drainage basin | 31 |
| Description of basin | 31 |
| Sinlahekin Creek near Loomis, Wash | 31 |
| Salmon Creek near Malott, Wash | 32 |
| Methow River drainage basin | 34 |
| Description of basin | 34 |
| Methow River near Pateros, Wash | 35 |
| Chelan River drainage basin | 37 |
| Description of basin | 37 |
| Lake Chelan at Chelan, Wash | 37 |
| Chelan River below Lake Chelan, Wash | 38 |
| Wenatchee River drainage basin | 40 |
| Description of basin | 40 |
| Wenatchee River at Cashmere, Wash | 40 |




Digitized by Google

Columbia River drainage basin—Continued. Page.
Yakima River drainage basin..... 43
Description of basin..... 43
Yakima River near Martin, Wash..... 43
Yakima River near North Yakima, Wash..... 45
Yakima River near Yakima, Wash..... 46
Yakima River at Prosser, Wash..... 48
Yakima River at Kiona, Wash..... 49
Canals in Yakima Valley, Wash..... 52
Cascade canal near Thorp, Wash..... 54
West Kittitas canal near Thorp, Wash..... 55
Town canal near Ellensburg, Wash..... 55
Olsen canal near Ellensburg, Wash..... 56
Selah-Moxee canal near North Yakima, Wash..... 57
Taylor canal near North Yakima, Wash..... 57
Moxee canal near North Yakima, Wash..... 58
Hubbard canal near North Yakima, Wash..... 59
Fowler canal near North Yakima, Wash..... 59
New Reservation canal in Yakima Indian Reservation, Wash..... 60
Old Reservation canal in Yakima Indian Reservation, Wash..... 61
Sunnyside canal near Yakima, Wash..... 61
Benton Water Company's canal near Kiona, Wash..... 62
Kiona canal near Kiona, Wash..... 63
Kiona Water Supply Company's canal near Kiona, Wash..... 63
Kennewick canal near Kennewick, Wash..... 64
Grosscup canal near Kiona, Wash..... 65
Selah Valley canal near North Yakima, Wash..... 65
Wapatox canal near North Yakima, Wash..... 66
Fortune canal near North Yakima, Wash..... 67
Lower Scott canal near North Yakima, Wash..... 67
Clark canal near North Yakima, Wash..... 68
Lowery canal near North Yakima, Wash..... 68
Gleed canal near North Yakima, Wash..... 69
Yakima Valley canal near North Yakima, Wash..... 70
White & Leach canal near North Yakima, Wash..... 71
McCormick canal near North Yakima, Wash..... 72
Naches-Cowiche canal near North Yakima, Wash..... 73
Broadgauge canal near North Yakima, Wash..... 73
Power canal at North Yakima, Wash..... 74
Shanno canal at North Yakima, Wash..... 75
Union canal at North Yakima, Wash..... 76
Town canal at North Yakima, Wash..... 76
Kachess Lake near Easton, Wash..... 78
Kachess River near Easton, Wash..... 78
Cle-alum River near Roslyn, Wash..... 80
Naches River near Nile, Wash..... 82
Naches River below mouth of Tieton River, Wash..... 84
Naches River near North Yakima, Wash..... 86
Tieton River near North Yakima, Wash..... 89
Snake River drainage basin..... 91
Description of basin..... 91
North Fork of Snake River, near Ora, Idaho..... 91
Snake River, near Minidoka, Idaho..... 93

Digitized by Google

Columbia River drainage basin—Continued. Page.
Snake River drainage basin—Continued.
Low-water conditions on Snake River between Blackfoot and Shoshone Falls, Idaho. 96
Fall River at Fremont, Idaho. 97
Teton River near St. Anthony, Idaho. 99
South Fork of Snake River at Moran, Wyo. 101
South Fork of Snake River near Lyon, Idaho. 103
Blackfoot River near Presto, Idaho. 106
Big Lost River near Mackay, Idaho. 108
Big Lost River near Chilly, Idaho. 110
Big Wood River near Gimlet, Idaho. 112
Big Wood River near Shoshone, Idaho. 113
Little Wood River near Carey, Idaho. 113
Succor Creek near Homedale, Idaho. 114
Owyhee River near Owyhee, Oreg. 116
Ditches in Owyhee River Valley, Oregon. 118
Owyhee Ditch near Owyhee, Oreg. 118
Wilson Ditch near Ontario, Oreg. 121
Boise River near Highland, Idaho. 121
Malheur River near Westfall, Oreg. 124
Malheur River at Vale, Oreg. 126
Malheur River at McLaughlin's bridge near Vale, Oreg. 129
Malheur River at Halliday's bridge, near Ontario, Oreg. 131
Ditches in Malheur River Valley, Oregon. 133
Vines Ditch above Vale, Oreg. 133
Malheur Farmers' canal above Vale, Oreg. 134
McLaughlin ditch above Vale, Oreg. 134
"J. H." ditch above Vale, Oreg. 135
Linebarger ditch above Vale, Oreg. 135
Gellerman & Frohman ditch above Vale, Oreg. 135
Sand Hollow ditch above Vale, Oreg. 136
Hope Mill ditch at Vale, Oreg. 136
Nevada ditch below Vale, Oreg. 136
Brosnan ditch near Ontario, Oreg. 137
Bully Creek above Vale, Oreg. 137
Bully Creek at Vale, Oreg. 140
Willow Creek near Malheur, Oreg. 141
Willow Creek near Dell, Oreg. 143
Ditches in Willow Creek Valley near Vale, Oreg. 146
Powder River near Baker City, Oreg. 148
Grande Ronde River at Hilgard, Oreg. 150
Grande Ronde River at Elgin, Oreg. 153
Grande Ronde River at Zindel, Wash. 155
Wallowa Lake near Joseph, Oreg. 156
Wallowa River near Joseph, Oreg. 156
Wallowa River near Wallowa, Oreg. 159
Wallowa River near Elgin, Oreg. 161
Ditches in Wallowa River Valley, Oregon. 163
Silver Lake ditch near Joseph, Oreg. 163
Farmers and Citizens' ditch near Joseph, Oreg. 164
Granger ditch at Joseph, Oreg. 165
Big Bend ditch at Joseph, Oreg. 165
Company ditch near Wallowa, Oreg. 166

Digitized by Google

Columbia River drainage basin—Continued. Page.
Snake River drainage basin—Continued.
Asotin Creek 1¼ miles above Asotin, Wash. 167
Asotin Creek at Shelman's ranch, near Asotin, Wash. 168
Palouse River at Elberton, Wash. 169
Palouse River at Hooper, Wash. 171
Rock Creek near St. John, Wash. 173
Cow Creek near Keystone, Wash. 175
Walla Walla River drainage basin. 176
Description of basin. 176
South Fork of Walla Walla River near Milton, Oreg. 176
Walla Walla River above Milton, Oreg. 178
Walla Walla River at Milton, Oreg. 179
Umatilla River drainage basin. 181
Description of basin. 181
Umatilla River at Gibbon, Oreg. 181
Umatilla River at Pendleton, Oreg. 184
Umatilla River at Yoakum, Oreg. 185
Umatilla River near Umatilla, Oreg. 188
Ditches in Umatilla River Valley, Oregon. 190
Farmers' mill ditch at Pendleton, Oreg. 190
Horseshoe Irrigation Company's ditch at Yoakum, Oreg. 191
Slusher & Gould ditch near Nolin, Oreg. 191
Lisle & Crane ditch near Echo, Oreg. 191
Charles Lisle ditch at Echo, Oreg. 192
Henrietta mill ditch at Echo, Oreg. 192
Wilson & Co.'s ditch at Echo, Oreg. 194
Allen ditch at Echo, Oreg. 194
Hinkle ditch at Echo, Oreg. 195
Pioneer ditch at Echo, Oreg. 196
Maxwell ditch at Echo, Oreg. 197
Hermiston ditch near Hermiston, Oreg. 198
Beitle ditch near Hermiston, Oreg. 199
Oregon Land and Water Company's ditch at Umatilla, Oreg. 199
Brownell ditch at Umatilla, Oreg. 201
Bowman ditch at Umatilla, Oreg. 201
Springs in Umatilla River Valley, Oregon. 201
Willow Creek drainage basin. 202
Description of basin. 202
Willow Creek near Arlington, Oreg. 202
John Day River drainage basin. 203
Description of basin. 203
John Day River at McDonald, Oreg. 203
Rock Creek near Arlington, Oreg. 206
Deschutes River drainage basin. 207
Description of basin. 207
Deschutes River near Bend, Oreg. 208
East Fork of Deschutes River at Odell, Oreg. 210
Deschutes River near Lava, Oreg. 212
West Fork of Deschutes River near Lava, Oreg. 214
Canals in Deschutes River Valley, Oregon. 216
Findley's ditch near Rosland, Oreg. 216
Central Oregon canal near Bend, Oreg. 216

Digitized by Google

Columbia River drainage basin—Continued. Page.
Deschutes River drainage basin—Continued.
Canals in Deschutes River Valley, Oregon—Continued.
Pilot Butte canal near Bend, Oreg ... 217
Columbia Southern canal near Bend, Oreg ... 219
Carmichael ditch at Prineville, Oreg ... 219
Hood River drainage basin ... 219
Hood River at Winans City, Oreg ... 219
Willamette River drainage basin ... 220
Description of basin ... 220
Middle Fork of Willamette River at Jasper, Oreg ... 220
Coast Fork of Willamette River near Goshen, Oreg ... 221
McKenzie River at Hendricks Ferry, Oreg ... 222
Willamette River at Albany, Oreg ... 223
Santiam River at Jefferson, Oreg ... 224
North Fork of Santiam River near Mehama, Oreg ... 224
South Fork of Santiam River at Waterloo, Oreg ... 225
Luckiamute River near Suver, Oreg ... 226
Molalla River at Dickey Prairie, Oreg ... 227
Clackamas River near Barton, Oreg ... 228
Miscellaneous measurements in Columbia River drainage basin ... 228
Puget Sound drainage basin ... 230
White River drainage basin ... 230
Cedar River near Ravensdale, Wash ... 230
Snohomish River drainage basin ... 232
South Fork of Skykomish River near Index, Wash ... 232
Snoqualmie River near Snoqualmie Falls, Washington ... 233

## ILLUSTRATIONS.

PLATE I. Map of the United States, showing location of principal river stations maintained during 1905 ... 2
FIG. 1. Cable station, showing section of river, car, gage, etc ... 7
2. Rating, area, and mean velocity curves for South Fork of Skykomish River near Index, Wash ... 10

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# PROGRESS REPORT OF STREAM MEASUREMENTS FOR THE CALENDAR YEAR 1905.

## PART XIV.

By D. W. Ross, J. T. Whistler, and T. A. Noble.

## INTRODUCTION.

### ORGANIZATION AND SCOPE OF WORK.

The hydrographic work of the United States Geological Survey includes the collection of facts concerning and the study of conditions affecting the behavior of water from the time it reaches the earth as rain or snow until it joins the oceans or great navigable rivers. These investigations became a distinct feature of the work of the Survey in the fall of 1888, when an instruction camp was established at Embudo, N. Mex. The first specific appropriation for gaging streams was made by the act of August 18, 1894, which contained an item of $12,500 "for gauging the streams and determining the water supply of the United States, including the investigation of underground currents and artesian wells in the arid and semiarid sections." (28 Stat. L., p. 398.)

Since that time the appropriations have been gradually increased, as shown by the following table:

*Annual appropriation for hydrographic surveys, fiscal years ending June 30, 1895 to 1906.*

| | | | |
|---|---|---|---|
| 1895 | $12,500 | 1901 | $100,000 |
| 1896 | 20,000 | 1902 | 100,000 |
| 1897 | 50,000 | 1903 | 200,000 |
| 1898 | 50,000 | 1904 | 200,000 |
| 1899 | 50,000 | 1905 | 200,000 |
| 1900 | 50,000 | 1906 | 200,000 |

As a result of the increased appropriations the work has been greatly extended, and at the same time it has been more thoroughly sytemized by the adoption of standard methods and by grouping the States into districts, in each of which a district hydrographer and a corps of assistants carry on a comprehensive study of the hydrographic resources.

The chief features of the hydrographic work are the collection of data relating to the flow of the surface waters and the study of the conditions affecting this flow. Information is also collected concerning river profiles, duration and magnitude of floods, water power, etc., which may be of use in hydrographic studies. This work includes the study of the hydrography of every important river basin in the United States, and is of direct value in the commercial and agricultural development of the country.

In order to collect the material from which estimates of daily flow are made, gaging stations are established. The selection of a site for a gaging station and the length of time it is maintained depend largely on the physical features and the needs of each locality. If the water is to be used for power, special effort is made to obtain information concerning the minimum flow; if water is to be stored, the maximum flow receives special attention.



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In all sections of the country permanent gaging stations are maintained for general statistical purposes, to show the conditions existing through long periods. They are also used as primary stations, and their records, in connection with short series of measurements, serve as bases for estimating the flow at other points in the drainage basin.

During the calendar year 1905 the division of hydrography has continued measuring the flow of streams on the same general lines as in previous years. Many new and improved methods have been introduced, by which the accuracy and value of the results have been increased. Approximately 800 regular gaging stations were maintained during the year, and an exceptionally large number of miscellaneous measurements and special investigations were made. "The Report of Progress of Stream Measurements," which contains the results of this work, is published in a series of fourteen Water-Supply and Irrigation Papers, Nos. 165–178, as follows:

No. 165. Atlantic coast of New England drainage.
No. 166. Hudson, Passaic, Raritan, and Delaware river drainages.
No. 167. Susquehanna, Gunpowder, Patapsco, Potomac, James, Roanoke, and Yadkin river drainages.
No. 168. Santee, Savannah, Ogeechee, and Altamaha rivers, and eastern Gulf of Mexico drainages.
No. 169. Ohio and lower eastern Mississippi river drainages.
No. 170. Great Lakes and St. Lawrence River drainages.
No. 171. Hudson Bay, and upper eastern and western Mississippi River drainages.
No. 172. Missouri River drainage.
No. 173. Meramec, Arkansas, Red, and lower western Mississippi river drainages.
No. 174. Western Gulf of Mexico and Rio Grande drainages.
No. 175. Colorado River drainage.
No. 176. Great Basin drainage.
No. 177. Great Basin and Pacific Ocean drainages in California.
No. 178. Columbia River and Puget Sound drainages.

These papers embody the data collected at the regular gaging stations, the results of the computations based on the observations, and such other information as may have a direct bearing on the study of the subject, and include, as far as practicable, descriptions of the basins and the streams draining them.

For the purpose of introducing uniformity into the reports for the various years, the drainages of the United States have been divided into eleven grand divisions, which have been again divided into secondary divisions, as shown in the following list. The Progress Report has been made to conform to this arrangement, each part containing the data for one or more of the secondary divisions. The secondary divisions have in most cases been redivided, and the facts have been arranged, as far as practicable, geographically.

*Drainage basins in the United States.*

NORTHERN ATLANTIC DRAINAGE BASINS.

St. John.
St. Croix.
Penobscot.
Kennebec.
Androscoggin.
Presumpscot.
Saco.
Merrimac.
Connecticut.
Blackstone.
Thames.
Housatonic.
Hudson.
Passaic.
Raritan.
Delaware.
Susquehanna.
Potomac.
Minor Chesapeake Bay.
Minor northern Atlantic.

SOUTHERN ATLANTIC DRAINAGE BASINS.

James.
Chowan.
Roanoke.
Tar.
Neuse.
Cape Fear.
Great Pedee (Yadkin).
Santee.
Savannah.
Ogeechee.
Altamaha.
Minor southern Atlantic.

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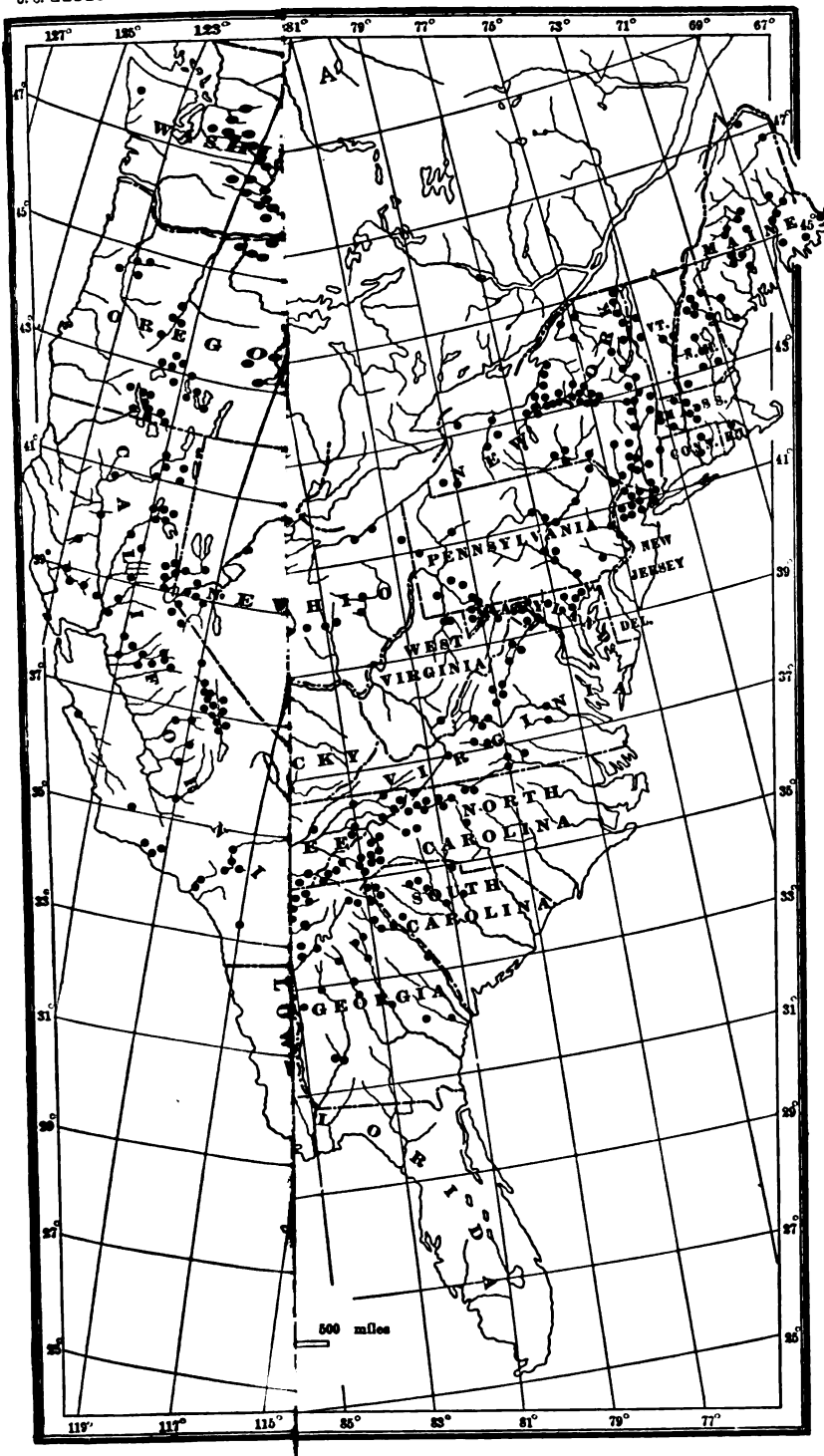


DURING 1905.

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EASTERN GULF OF MEXICO DRAINAGE BASINS.

Suwanee.
Apalachicola.
Mobile.
Pearl.
Minor eastern Gulf of Mexico.

EASTERN MISSISSIPPI RIVER DRAINAGE BASINS.

Lower eastern Mississippi.
Ohio.
Upper eastern Mississippi.

ST. LAWRENCE RIVER DRAINAGE BASINS.

Lake Superior.
Lake Michigan.
Lake Huron.
Lake St. Clair.
Lake Erie.
Niagara River.
Lake Ontario.
Lake Champlain (Richelieu River).
Minor St. Lawrence.

WESTERN MISSISSIPPI RIVER DRAINAGE BASINS.

Upper western Mississippi.
Missouri.
Meramec.
Lower western Mississippi.
Arkansas.
Red.

WESTERN GULF OF MEXICO DRAINAGE BASINS.

Sabine.
Neches.
Trinity.
Brazos.
Colorado (of Texas).
Guadalupe.
San Antonio.
Nueces.
Rio Grande.
Minor western Gulf of Mexico.

COLORADO RIVER DRAINAGE BASIN.

GREAT BASIN.

Wasatch Mountains.
Humboldt.
Sierra Nevada.
Minor streams in Great Basin.

PACIFIC COAST DRAINAGE BASINS.

Southern Pacific.
San Francisco Bay.
Northern Pacific.
Columbia.
Puget Sound.

HUDSON BAY DRAINAGE BASINS.

## DEFINITIONS.

The volume of water flowing in a stream—the "run-off" or "discharge"—is expressed in various terms, each of which has become associated with a certain class of work. These terms may be divided into two groups—(1) those which represent a rate of flow, as second-feet, gallons per minute, miner's inch, and run-off in second-feet per square mile; and (2) those which represent the actual quantity of water, as run-off in depth in inches and acre-feet. They may be defined as follows:

"Second-foot" is an abbreviation for cubic foot per second, and is the rate of discharge of water flowing in a stream 1 foot wide, 1 foot deep, at a rate of 1 foot per second. It is generally used as a fundamental unit from which others are computed.

"Gallons per minute" is generally used in connection with pumping and city water supply.

The "miner's inch" is the rate of discharge of water passing through an orifice 1 inch square under a head which varies locally. It has been commonly used by miners and irrigators throughout the West, and is defined by statute in each State in which it is used. In most States the California miner's inch is used, which is the fiftieth part of a second-foot.

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly, both as regards time and area.

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"Run-off in inches" is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed on the surface. It is used for comparing run-off with rainfall, which is usually expressed in depth in inches.

"Acre-foot" is equivalent to 43,560 cubic feet, and is the quantity required to cover an acre to the depth of 1 foot. It is commonly used in connection with storage for irrigation work. There is a convenient relation between the second-foot and the acre-foot. One second-foot flowing for twenty-four hours will deliver 86,400 cubic feet, or approximately 2 acre-feet.

## EXPLANATION OF TABLES.

For each regular gaging station are given, as far as available, the following data:

1. Description of station.
2. List of discharge measurements.
3. Gage-height table.
4. Rating table.
5. Table of estimated monthly and yearly discharges and run-off, based on all the facts obtained to date.

The descriptions of stations give such general information about the locality and equipment as would enable the reader to find and use the station. They also give, as far as possible, a complete history of all the changes that have occurred since the establishment of the station that would be factors in using the data collected.

The discharge-measurement table gives the results of the discharge measurements made during the year, including the date, the name of the hydrographer, the gage height, the area of cross section, the mean velocity, and the discharge in second-feet.

The table of daily gage heights gives the daily fluctuations of the surface of the river as found from the mean of the gage readings taken each day. The gage height given in the table represents the elevation of the surface of the water above the zero of the gage. At most stations the gage is read in the morning and in the evening.

The rating table gives discharges in second-feet corresponding to each stage of the river as given by the gage heights.

In the table of estimated monthly discharge, the column headed "Maximum" gives the mean flow for the day when the mean gage height was highest; this is the flow as given in the rating table for that mean gage height. As the gage height is the mean for the day there might have been short periods when the water was higher and the corresponding discharge larger than given in this column. Likewise in the column of "Minimum," the quantity given is the mean flow for the day when the mean gage height was lowest. The column headed "Mean" is the average flow for each second during the month. On this the computations for the three remaining columns, which are defined above, are based.

In the computations for the tables of this report the following general and special rules have been used:

### *Fundamental rules for computation.*

1. The highest degree of precision consistent with the rational use of time and money is imperative.
2. All items of computation should be expressed by at least two and not more than four significant figures.
3. Any measurement in a vertical velocity, mean velocity, or discharge curve whose per cent of error is five times the average per cent of error of all the other measurements should be rejected.
4. In reducing the number of significant figures, or the number of decimal places, by dropping the last figure, the following rules apply:

(a) When the figure in the place to be rejected is less than 5, drop it without changing the preceding figure. Example: 1,827.4 becomes 1,827

(b) When the figure in the place to be rejected is greater than 5, drop it and increase the preceding figure by 1. Example: 1,827.6 becomes 1,828.

(c) When the figure in the place to be rejected is 5, and it is preceded by an even figure, drop the 5. Example: 1,828.5 becomes 1,828.

(d) When the figure in the place is to be rejected is 5, and it is preceded by an odd figure, drop the 5 and increase the preceding figure by 1. Example: 1,827.5 becomes 1,828.

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*Special rules for computation.*

1. Rating tables are to be constructed as closely as the data on which they are based will warrant. No decimals are to be used when the discharge is over 50 second-feet.

2. Daily discharges shall be applied directly to the gage heights as they are tabulated.

3. Monthly means are to be carried out to one decimal place when the quantities are below 100 second-feet. Between 100 and 10,000 second-feet, the last figure in the monthly mean shall be a significant figure. This also applies to the yearly mean.

4. Second-feet per square mile and depth in inches for the individual months shall be carried out to at least three significant figures, except in the case of decimals where the first significant figure is preceded by one or more naughts (0), when the quantity shall be carried out to two significant figures. Example: 1.25; .125; .012, .0012. The yearly means for these quantities are always to be expressed in three significant figures and at least two decimal places.

## CONVENIENT EQUIVALENTS.

1 second-foot equals 50 California miner's inches.
1 second-foot equals 38.4 Colorado miner's inches.
1 second-foot equals 40 Arizona miner's inches.
1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646,272 gallons for one day.
1 second-foot equals 6.23 British imperial gallons per second.
1 second-foot for one year covers 1 square mile 1.131 feet deep, 13.572 inches deep.
1 second-foot for one year equals 0.000214 cubic mile; equals 31,536,000 cubic feet.
1 second-foot equals about 1 acre-inch per hour.
1 second-foot falling 10 feet equals 1.136 horsepower.
100 California miner's inches equal 15 United States gallons per second.
100 California miner's inches equal 77 Colorado miner's inches.
100 California miner's inches for one day equal 4 acre-feet.
100 Colorado miner's inches equal 2.60 second-feet.
100 Colorado miner's inches equal 19.5 United States gallons per second.
100 Colorado miner's inches equal 130 California miner's inches.
100 Colorado miner's inches for one day equal 5.2 acre-feet.
100 United States gallons per minute equal 0.223 second-foot.
100 United States gallons per minute for one day equal 0.44 acre-foot.
1,000,000 United States gallons per day equal 1.55 second-feet.
1,000,000 United States gallons equal 3.07 acre-feet.
1,000,000 cubic feet equal 22.95 acre-feet.
1 acre-foot equals 325,850 gallons.
1 inch deep on 1 square mile equals 2,323,200 cubic feet.
1 inch deep on 1 square mile equals 0.0737 second-foot per year.
1 inch equals 2.54 centimeters.
1 foot equals 0.3048 meter.
1 yard equals 0.9144 meter.
1 mile equals 1.60935 kilometers.
1 mile equals 1,760 yards; equals 5,280 feet; equals 63,360 inches.
1 square yard equals 0.836 square meter.
1 acre equals 0.4047 hectare.
1 acre equals 43,560 square feet; equals 4,840 square yards.
1 acre equals 209 feet square, nearly.
1 square mile equals 259 hectares.
1 square mile equals 2.59 square kilometers.
1 cubic foot equals 0.0283 cubic meter.
1 cubic foot equals 7.48 gallons; equals 0.804 bushel.
1 cubic foot of water weighs 62.5 pounds.
1 cubic yard equals 0.7646 cubic meter.
1 cubic mile equals 147,198,000,000 cubic feet.
1 cubic mile equals 4,667 second-feet for one year.
1 gallon equals 3.7854 liters.
1 gallon equals 8.36 pounds of water.
1 gallon equals 231 cubic inches (liquid measure).
1 pound equals 0.4536 kilogram.
1 avoirdupois pound equals 7,000 grains.
1 troy pound equals 5,760 grams.
1 meter equals 39.37 inches. Log. 1.5951654.
1 meter equals 3.280833 feet. Log. 0.5159842.
1 meter equals 1.093611 yards. Log. 0.0388629.
1 kilometer equals 3,281 feet; equals five-eighths mile, nearly.
1 square meter equals 10,764 square feet; equals 1,196 square yards.

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1 hectare equals 2.471 acres.
1 cubic meter equals 35.314 cubic feet; equals 1.308 cubic yards.
1 liter equals 1.0567 quarts.
1 gram equals 15.43 grains.
1 kilogram equals 2.2046 pounds.
1 tonneau equals 2,204.6 pounds.
1 foot per second equals 1,097 kilometers per hour.
1 foot per second equals 0.68 mile per hour.
1 cubic meter per minute equals 0.5886 second-foot.
1 atmosphere equals 15 pounds per square inch; equals 1 ton per square foot; equals 1 kilogram per square centimeter.
Acceleration of gravity equals 32.16 feet per second every second.
1 horsepower equals 550 foot-pounds per second.
1 horsepower equals 76 kilogram-meters per second.
1 horsepower equals 746 watts.
1 horsepower equals 1 second-foot falling 8.8 feet.
1½ horsepowers equal about 1 kilowatt.
To calculate water power quickly: $\frac{\text{Sec.-ft.} \times \text{fall in feet}}{11}$ = net horsepower on water wheel, realizing 80 per cent of the theoretical power.
Quick formula for computing discharge over weirs: Cubic feet per minute equals $0.4025\, l\, h^{\frac{3}{2}}$; $l$ = length of weir in inches; $h$ = head in inches flowing over weir, measured from surface of still water.
To change miles to inches on map:

Scale 1: 125,000, 1 mile = 0.50688 inch.
Scale 1: 90,000, 1 mile = 0.70400 inch.
Scale 1: 62,500, 1 mile = 1.01376 inches.
Scale 1: 45,000, 1 mile = 1.40800 inches.

## FIELD METHODS OF MEASURING STREAM FLOW.

The methods used in collecting these data and in preparing them for publication are given in detail in Water-Supply Papers No. 94 (Hydrographic Manual, U. S. Geol. Survey) and No. 95 (Accuracy of Stream Measurements). In order that those who use this report may readily become acquainted with the general methods employed, the following brief descriptions are given:

Streams may be divided, with respect to their physical conditions, into three classes—(1) Those with permanent beds; (2) those with beds which change only during extreme low or high water; and (3) those with constantly shifting beds. In estimating the daily flow special methods are necessary for each class. The data on which these estimates are based and the methods of collecting them are, however, in general the same.

There are three distinct methods of determining the flow of open-channel streams—(1) By measurements of slope and cross section and the use of Chezy's and Kutter's formulas; (2) by means of a weir; and (3) by measurements of the velocity of the current and of the area of the cross section. The method chosen for any case depends on the local physical conditions, the degree of accuracy desired, the funds available, and the length of time that the record is to be continued.

*Slope method.*—Much information has been collected relative to the coefficients to be used in the Chezy formula, $v = c\sqrt{rs}$. This has been utilized by Kutter, both in developing his formula for $c$ and in determining the values of the coefficient $n$ which appears therein. The results obtained by the slope method are in general only roughly approximate, owing to the difficulty in obtaining accurate data and the uncertainty of the value for $n$ to be used in Kutter's formula. The most common use of this method is in estimating the flood discharge of a stream when the only data available are the cross section, the slope as shown by marks along the bank, and a knowledge of the general conditions.

*Weir method.*—When funds are available and the conditions are such that sharp-crested weirs can be erected, these offer the best facilities for determining flow. If dams are suitably situated and constructed, they may be utilized for obtaining reliable estimates of flow. The conditions necessary to insure good results may be divided into two classes: (1) Those relating to the physical characteristics of the dam itself, and (2) those relating to the diversion and use of water around and through the dam.

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The physical requirements are as follows: (*a*) Sufficient height of dam, so that backwater will not interfere with free fall over it; (*b*) absence of leaks of appreciable magnitude; (*c*) topography or abutments which confine the flow over the dam at high stages; (*d*) level crests which are kept free from obstructions caused by floating logs or ice; (*e*) crests of a type for which the coefficients to be used in $Q=c\,b\,h^{\frac{3}{2}}$, or some similar standard weir formula, are known (see Water-Supply Paper No. 150); (*f*) either no flashboards or exceptional care in reducing leakage through them and in recording their condition.

Preferably there should be no diversion of water through or around the dam. Generally, however, the dam is built for purposes of power or navigation, and part or all of the water flowing past it is diverted for such uses. This water is measured and added to that passing over the dam. To insure accuracy in such estimates, the amount of water diverted should be reasonably constant. Furthermore, it should be so diverted that it can be measured, either by a weir, a current meter, or a simple system of water wheels which are of standard make, or which have been rated as meters under working conditions and so installed that the gate openings, the heads under which they work, and their angular velocities may be accurately observed.

The combination of physical conditions and uses of the water should be such that the estimates of flow will not involve, for a critical stage of considerable duration, the use of a head on a broad-crested dam of less than 6 inches. Moreover, when all other conditions are good, the cooperation of the owners or operators of the plant is still essential if reliable results are to be obtained.

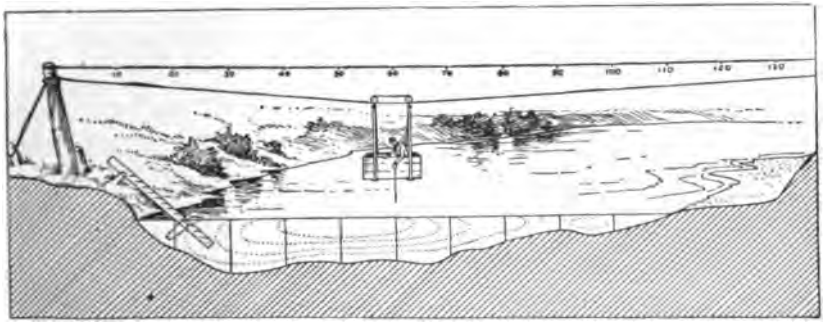

FIG. 1.—Cable station, showing section of river, car, gage, etc.

A gaging station at a weir or dam has the general advantage of continuity of record through the period of ice and floods and the disadvantages of uncertainty of coefficient to be used in the weir formula and of complications in the diversion and use of the water.

*Velocity method.*—The determination of the quantity of water flowing past a certain section of a stream at a given time is termed a discharge measurement. This quantity is the product of two factors—the mean velocity and the area of the cross section. The mean velocity is a function of surface slope, wetted perimeter, roughness of bed, and the channel conditions at, above, and below the gaging section. The area depends on the contour of the bed and the fluctuations of the surface. The two principal ways of measuring the velocity of a stream are by floats and current meters.

Great care is taken in the selection and equipment of gaging stations for determining discharge by velocity measurements in order that the data may have the required degree of accuracy. Their essential requirements are practically the same whether the velocity is determined by meters or floats. They are located as far as possible where the channel is straight both above and below the gaging section; where there are no cross currents, backwater, or boils; where the bed of the stream is reasonably free from large projections of a permanent character; and where the banks are high and subject to overflow only at flood stages. The station must be so far removed from the effects of tributary streams and dams or other artificial obstructions that the gage height shall be an index of the discharge.

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Certain permanent or semipermanent structures, usually referred to as "equipment," are generally pertinent to a gaging station. These are a gage for determining the fluctuations of the water surface, bench marks to which the datum of the gage is referred, permanent marks on a bridge or a tagged line indicating the points of measurement, and, where the current is swift, some appliance (generally a secondary cable) to hold the meter in position in the water. As a rule, the stations are located at bridges if the channel conditions are satisfactory, as from them the observations can more readily be made and the cost of the equipment is small.

The floats in common use are the surface, subsurface, and tube or rod floats. A corked bottle with a flag in the top and weighted at the bottom makes one of the most satisfactory surface floats, as it is affected but little by wind. In case of flood measurements, good results can be obtained by observing the velocity of floating cakes of ice or débris. In case of all surface-float measurements coefficients must be used to reduce the observed velocity to the mean velocity. The subsurface and tube or rod floats are intended to give directly the mean velocity in the vertical. Tubes give excellent results when the channel conditions are good, as in canals.

In measuring velocity by a float, observation is made of the time taken by the float to pass over the "run," a selected stretch of river from 50 to 200 feet long. In each discharge measurement a large number of velocity determinations are made at different points across the stream, and from these observations the mean velocity for the whole section is determined. This may be done by plotting the mean positions of the floats as indicated by the distances from the bank as ordinates and the corresponding times as abscissas. A curve through these points shows the mean time of run at any point across the stream, and the mean time for the whole stream is obtained by dividing the area bounded by this curve and its axis by the width. The length of the run divided by the mean time gives the mean velocity.

The area used in float measurements is the mean of the areas at the two ends of the run and at several intermediate sections.

The essential parts of the current meters in use are a wheel of some type, so constructed that the impact of flowing water causes it to revolve, and a device for recording or indicating the number of revolutions. The relation between the velocity of the moving water and the revolutions of the wheel is determined for each meter. This rating is done by drawing the meter through still water for a given distance at different speeds, and noting the number of revolutions for each run. From these data a rating table is prepared which gives the velocity per second for any number of revolutions.

Many kinds of current meters have been constructed. They may, however, be classed in two general types—those in which the wheel is made up of a series of cups, as the Price, and those having a screw-propeller wheel, as the Haskell. Each meter has been developed for use under some special condition. In the case of the small Price meter, which has been largely developed and extensively used by the United States Geological Survey, an attempt has been made to get an instrument which could be used under practically all conditions.

Current-meter measurements may be made from a bridge, cable, boat, or by wading, and gaging stations may be classified in accordance with such use. Fig. 1 shows a typical cable station.

In making the measurement an arbitrary number of points are laid off on a line perpendicular to the thread of the stream. The points at which the velocity and depth are observed are known as measuring points, and are usually fixed at regular intervals, varying from 2 to 20 feet, depending on the size and condition of the stream. Perpendiculars dropped from the measuring points divide the gaging section into strips. For each strip or pair of strips the mean velocity, area, and discharge are determined independently, so that conditions existing in one part of the stream may not be extended to parts where they do not apply.

Three classes of methods of measuring velocity with current meters are in general use—multiple-point, single-point, and integration.

The three principal multiple-point methods in general use are the vertical velocity-curve; 0.2 and 0.8 depth; and top, bottom, and mid-depth.

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In the vertical velocity-curve method a series of velocity determinations are made in each vertical at regular intervals, usually from 0.5 to 1 foot apart. By plotting these velocities as abscissas and their depths as ordinates, and drawing a smooth curve among the resulting points, the vertical velocity curve is developed. This curve shows graphically the magnitude and changes in velocity from the surface to the bottom of the stream. The mean velocity in the vertical is then obtained by dividing the area bounded by this velocity curve and its axis by the depth. On account of the length of time required to make a complete measurement by this method, its use is limited to the determination of coefficients for purposes of comparison and to measurements under ice.

In the second multiple-point method the meter is held successively at 0.2 and 0.8 of the depth, and the mean of the velocities at these two points is taken as the mean velocity for that vertical. On the assumption that the vertical velocity curve is a common parabola with horizontal axis, the mean of the velocities at 0.22 and 0.79 of the depth will give (closely) the mean velocity in the vertical. Actual observations under a wide range of conditions show that this second multiple-point method gives the mean velocity very closely for open-water conditions where the depth is over 5 feet and the bed comparatively smooth, and moreover the indications are that it will hold nearly as well for ice-covered rivers.

In the third multiple-point method the meter is held at mid-depth, at 0.5 foot below the surafce, and at 0.5 foot above the bottom, and the mean velocity is determined by dividing by 6 the sum of the top velocity, four times the mid-depth velocity, and the bottom velocity. This method may be modified by observing at 0.2, 0.6, and 0.8 depth.

The single-point method consists in holding the meter either at the depth of the thread of mean velocity, or at an arbitrary depth for which the coefficient for reducing to mean velocity has been determined.

Extensive experiments by vertical velocity curves show that the thread of mean velocity generally occurs at from 0.5 to 0.7 of the total depth. In general practice the thread of mean velocity is considered to be at 0.6 depth, at which point the meter is held in a majority of the measurements. A large number of vertical velocity-curve measurements, taken on many streams and under varying conditions, show that the average coefficient for reducing the velocity obtained at 0.6 depth to mean velocity is practically unity.

In the other principal single-point method the meter is held near the surface, usually 1 foot below, or low enough to be out of the effect of the wind or other disturbing influences. This is known as the subsurface method. The coefficient for reducing the velocity taken at the subsurface to the mean has been found to be from 0.85 to 0.95, depending on the stage, velocity, and channel conditions. The higher the stage the larger the coefficient. This method is specially adapted for flood measurements, or when the velocity is so great that the meter can not be kept at 0.6 depth.

The vertical-integration method consists in moving the meter at a slow, uniform speed from the surface to the bottom and back again to the surface, and noting the number of revolutions and the time taken in the operation. This method has the advantage that the velocity at each point of the vertical is measured twice. It is well adapted for measurements under ice and as a check on the point methods.

The area, which is the other factor in the velocity method of determining the discharge of a stream, depends on the stage of the river, which is observed on the gage, and on the general contour of the bed of the stream, which is determined by soundings. The soundings are usually taken at each measuring point at the time of the discharge measurement, either by using the meter and cable, or by a special sounding line or rod. For streams with permanent beds standard cross sections are usually taken during low water. These sections serve to check the soundings which are taken at the time of the measurements, and from them any change which may have taken place in the bed of the stream can be detected. They are also of value in obtaining the area for use in computations of high-water measurements, as accurate soundings are hard to obtain at high stages.

In computing the discharge measurements from the observed velocities and depths at various points of measurement the measuring section is divided into elementary strips, as



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shown in fig. 1, and the mean velocity, area, and discharge are determined separately for either a single or a double strip. The total discharge and the area are the sums of those for the various strips, and the mean velocity is obtained by dividing the total discharge by the total area.

The determination of the flow of an ice-covered stream is difficult, owing to diversity and instability of conditions during the winter period and also to lack of definite information in regard to the laws of flow of water under ice. The method now employed is to make frequent discharge measurements during the frozen periods by the vertical velocity-curve method and to keep an accurate record of the conditions, such as the gage height to the surface of the water as it rises in a hole cut in the ice, the thickness and character of the ice, etc.

From these data an approximate estimate of the daily flow can be made by constructing a rating curve (really a series of curves) similar to that used for open channels, but considering, in addition to gage heights and discharge, the varying thickness of ice. Such data as are available in regard to this subject are published in Water-Supply Paper No. 146, pp. 141–148.

## OFFICE METHODS OF COMPUTING RUN-OFF.

There are two principal methods of estimating run-off, depending on whether or not the bed of the stream is permanent.

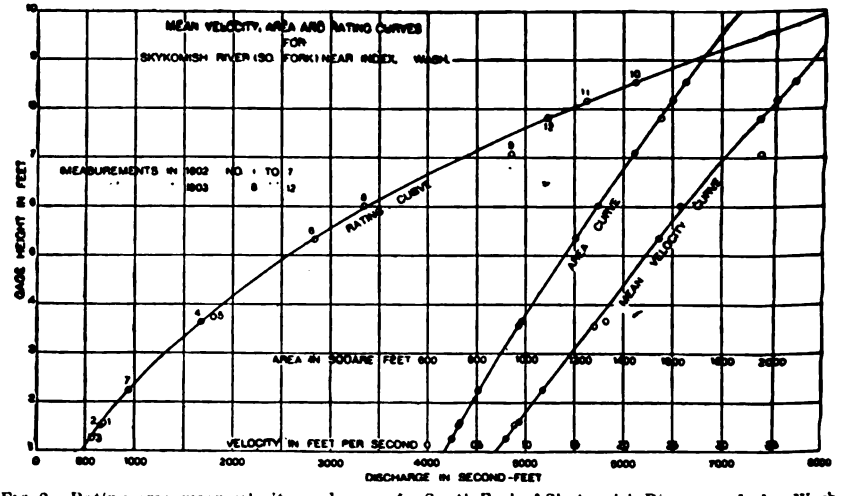


FIG. 2.—Rating, area, mean velocity, and curves for South Fork of Skykomish River near Index, Wash.

For stations on streams with permanent beds the first step in computing the run-off is the construction of a rating table, which shows the discharge corresponding to any stage of the stream. This rating table is applied to the record of stage to determine the amount of water flowing. The construction of the rating table depends on the method used in measuring flow.

For a station at a weir or dam the basis for the rating table is some standard weir formula. The coefficients to be used in its application depend on the type of dam and other conditions near its crest. After inserting in the weir formula the measured length of crest and the assumed coefficient the discharge is computed for various heads and the rating table constructed.

The data necessary for the construction of a rating table for a velocity-area station are the results of the discharge measurements, which include the record of stage of the river at the time of measurement, the area of the cross section, the mean velocity of the current, and the quantity of water flowing. A thorough knowledge of the conditions at and in the vicinity of the station is also necessary.

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The construction of the rating table depends on the following laws of flow for open, permanent channels: (1) The discharge will remain constant so long as conditions at or near the gaging station remain constant; (2) the discharge will be the same whenever the stream is at a given stage if the change of slope due to the rise and fall of the stream be neglected; (3) the discharge is a function of and increases gradually with the stage.

The plotting of results of the various discharge measurements, using gage heights as ordinates, and discharge, mean velocity, and area as abscissas, will define curves which show the discharge, mean velocity, and area corresponding to any gage height. For the development of these curves there should be, therefore, a sufficient number of discharge measurements to cover the range of the stage of the stream. Fig. 2 shows a typical rating curve with its corresponding mean velocity and area curves.

As the discharge is the product of two factors, the area and the mean velocity, any change in either factor will produce a corresponding change in the discharge. Their curves are therefore constructed in order to study each independently of the other.

The area curve can be definitely determined from accurate soundings extending to the limits of high water. It is always concave toward the horizontal axis or on a straight line, unless the banks of the stream are overhanging.

The form of the mean velocity curve depends chiefly on the surface slope, the roughness of the bed, and the cross section of the stream. Of these, the slope is the principal factor. In accordance with the relative changes of these factors the curve may be either a straight line, convex or concave toward either axis, or a combination of the three. From a careful study of the conditions at any gaging station the form which the vertical velocity curve will take can be predicted, and it may be extended with reasonable certainty to stages beyond the limits of actual measurements. Its principal use is in connection with the area curve in locating errors in discharge measurements and in constructing the rating table.

The discharge curve is defined primarily by the measurements of discharge, which are studied and weighted in accordance with the local conditions existing at the time of each measurement. The curve may, however, best be located between and beyond the measurements by means of curves of area and mean velocity. The discharge curve under normal conditions is concave toward the horizontal axis and is generally parabolic in form.

In the preparation of the rating table the discharge for each tenth or half tenth on the gage is taken from the curve. The differences between successive discharges are then taken and adjusted according to the law that they shall either be constant or increasing.

The determination of daily discharge of streams with changeable beds is a difficult problem. In case there is a weir or dam available, a condition which seldom exists on streams of this class, estimates can be obtained by its use. In case of velocity-area stations frequent discharge measurements must be made if the estimates are to be other than rough approximations. For stations with beds which shift slowly or are materially changed only during floods rating tables can be prepared for periods between such changes and satisfactory results obtained with a limited number of measurements, provided that some of them are taken soon after the change occurs. For streams with continually shifting beds, such as the Colorado and Rio Grande, discharge measurements should be made every two or three days and the discharges for intervening days obtained either by interpolation modified by gage height or by Professor Stout's method, which has been described in full in the Nineteenth Annual Report of the United States Geological Survey, Part IV, page 323, and in the Engineering News of April 21, 1904. This method, or a graphical application of it, is also much used in estimating flow at stations where the bed shifts but slowly.

## COOPERATION AND ACKNOWLEDGMENTS.

Most of the measurements presented in this paper have been obtained through local hydrographers. Acknowledgment is extended to other persons and corporations who have assisted local hydrographers or have cooperated in any way, either by furnishing records of the height of water or by assisting in transportation.

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The following is a list, arranged alphabetically by States, of the hydrographers and others who have assisted in furnishing and preparing the data contained in this report.

*Idaho.*—Supervising engineer, D. W. Ross,[a] assisted by L. C. LaRue, William G. Davies, and J. B. Bond. Acknowledgments and thanks are due the Oregon Short Line Railroad for transportation furnished the district engineer and his assistants.

*Montana.*—District engineer, C. C. Babb,[b] assisted by L. R. Stockman, H. M. Morse, and J. H. Sloan. Acknowledgments are due the Northern Pacific Railway for transportation furnished the hydrographers.

*Oregon.*—District engineer, John T. Whistler,[c] assisted by Wilbur C. Sawyer, E. N. Smith, Ivan Landes, and R. S. Hall. Acknowledgments and thanks are due the Oregon Railroad and Navigation Company, Southern Pacific Company, Oregon Short Line Railroad, Sumpter Valley Railway, and Columbia Southern Railway for transportation; to W. G. McDonald for the use of his ferry cable on John Day River as a gaging station, and to the Deschutes Irrigation and Power Company, Bend, Oreg., for voluntary gage readings.

*Washington.*—District engineer, T. A. Noble, assisted by W. J. Lightfoot, W. C. Muldrow, and others. Acknowledgments and thanks are due to the many owners and managers of irrigation canals in Yakima River Valley for assistance and information furnished in the prosecution of the work in that locality.

*Wyoming.*—District hydrographer, M. C. Hinderlider,[d] and resident hydrographer, A. J. Parshall. Acknowledgments are due for annual passes over all their lines in Wyoming to the Union Pacific; Chicago, Burlington and Quincy; Colorado and Southern; Colorado and Wyoming; and Fremont Elkhorn and Missouri Valley railroads.

## COLUMBIA RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Next to the Colorado, Columbia River drains the largest area of all the rivers in the arid region, its drainage including parts of Washington, Oregon, Idaho, Montana, and a large area in Canada. No extensive observations of its flow have been made, but the data obtained indicate that its discharge is much greater than that of the Colorado. The Columbia and its numerous tributaries are of great importance, offering good sites for water power development and an abundance of water for irrigation, while the main river is navigable for a considerable distance.

Columbia River for most of its length in Washington and Oregon flows through a deep canyon, and can not be economically diverted for irrigation to any considerable extent, though there is one point at Priest Rapids where a very large amount of power can be economically developed and considerable land irrigated by gravity and a water-power pumping plant.

The tributaries which do not flow through deep canyons are extensively used for irrigation, and afford many opportunities for the installation of large water-power plants and extensive irrigation development in the future.

The following pages give the results of data collected in the Columbia River drainage basin during 1905.

### COLUMBIA RIVER NEAR JULIA, WASH.

This station was established by the Reclamation Service March 1, 1905, for the study of the regimen of rise and fall of Columbia River, and was discontinued October 1, 1905. It is located near Koppen's house, at Wahluke, near Julia, Wash.

The channel is straight for 4,000 feet above and 3,000 feet below the station. The current is sluggish. Both banks are high, rocky, clean, and not liable to overflow during high water.

The gage is on the north bank of the river, and is in two sections. The lower is an inclined staff, graduated to read direct to 20 feet, and the upper is a vertical staff, graduated from 20 to 24 feet. The bench mark is a spike nail driven into the base log at the southwest corner of the observer's house, 600 feet northeast of the gage; elevation, 39.52 feet above gage datum. The gage is read twice each day by Jennie C. Koppen.

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[a] Office of supervising engineer, Boise, Idaho.
[b] District office for 1906 will be at Huntley, Mont., H. M. Morse, hydrographer in charge.
[c] District office for Oregon and Washington, 1906, will be 351 Washington street, Portland, Oreg., J. C. Stevens, hydrographer in charge.
[d] Office of the district hydrographer, Chamber of Commerce Building, Denver, Colo.

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*Daily gage height, in feet, of Columbia River near Julia, Wash., for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|
| 1 | 2.0 | 4.8 | 7.45 | 12.2 | 14.3 | 11.75 | 7.62 |
| 2 | 2.28 | 4.78 | 7.5 | 12.52 | 14.12 | 11.7 | 7.4 |
| 3 | 2.22 | 4.77 | 7.58 | 13.12 | 14.0 | 11.62 | 7.22 |
| 4 | 2.42 | 4.7 | 7.6 | 13.7 | 13.92 | 11.52 | 7.12 |
| 5 | 2.58 | 4.7 | 7.6 | 14.05 | 13.88 | 11.45 | 6.95 |
| 6 | 2.7 | 4.65 | 7.68 | 14.08 | 13.82 | 11.45 | 6.78 |
| 7 | 2.88 | 4.6 | 7.8 | 14.88 | 13.72 | 11.4 | 6.62 |
| 8 | 3.0 | 4.65 | 7.95 | 15.15 | 13.55 | 11.35 | 6.5 |
| 9 | 3.15 | 4.7 | 8.18 | 15.55 | 13.4 | 11.3 | 6.38 |
| 10 | 3.32 | 4.7 | 8.48 | 15.98 | 13.3 | 11.25 | 6.35 |
| 11 | 3.52 | 4.75 | 8.7 | 16.28 | 13.25 | 11.2 | 6.28 |
| 12 | 3.8 | 4.75 | 9.0 | 16.48 | 13.2 | 11.15 | 6.18 |
| 13 | 3.8 | 4.75 | 9.0 | 16.55 | 13.15 | 11.0 | 6.15 |
| 14 | 3.88 | 4.82 | 9.1 | 16.72 | 13.1 | 11.98 | 6.15 |
| 15 | 3.9 | 4.88 | 9.2 | 16.85 | 13.02 | 10.88 | 6.13 |
| 16 | 3.98 | 4.92 | 9.35 | 16.9 | 12.92 | 10.88 | 6.08 |
| 17 | 3.96 | 4.98 | 9.48 | 16.75 | 12.88 | 10.78 | 6.0 |
| 18 | 3.98 | 5.0 | 9.68 | 16.4 | 12.78 | 10.62 | 5.98 |
| 19 | 4.0 | 5.0 | 9.92 | 16.28 | 12.68 | 10.45 | 5.88 |
| 20 | 4.12 | 5.08 | 10.1 | 16.15 | 12.5 | 10.15 | 5.82 |
| 21 | 4.4 | 5.18 | 10.08 | 15.85 | 12.25 | 9.9 | 5.75 |
| 22 | 4.45 | 5.35 | 10.12 | 15.65 | 12.12 | 9.65 | 5.75 |
| 23 | 4.6 | 5.55 | 10.35 | 15.48 | 11.98 | 9.45 | 5.7 |
| 24 | 4.7 | 5.9 | 10.42 | 15.4 | 11.92 | 9.2 | 5.65 |
| 25 | 4.75 | 6.52 | 10.5 | 15.32 | 11.88 | 8.98 | 5.65 |
| 26 | 4.7 | 6.78 | 10.75 | 15.22 | 11.78 | 8.68 | 5.65 |
| 27 | 4.77 | 7.05 | 10.92 | 15.1 | 11.78 | 8.45 | 5.68 |
| 28 | 4.75 | 7.42 | 11.2 | 14.8 | 11.73 | 8.25 | 5.78 |
| 29 | 4.8 | 7.6 | 11.48 | 14.68 | 11.75 | 8.05 | 5.95 |
| 30 | 4.8 | 7.5 | 11.75 | 14.5 | 11.75 | 7.85 | 6.12 |
| 31 | 4.77 | ..... | 11.95 | ..... | 11.75 | 7.73 | ..... |

## COLUMBIA RIVER NEAR PASCO, WASH.

This station was established October 15, 1904, by C. B. Cox. It is located at the bridge of the Northern Pacific Railway 1.2 miles from Pasco, Wash.

The channel is curved for about 800 feet above and straight for about one-fourth mile below the station. The water above the station is smooth. It becomes swift and rough on the west side of the channel 600 feet below the station. Both banks overflow during high water. The bed of the stream is composed of bowlders, and is fairly permanent. There is one channel at high and two at very low stages. The piers of the bridge, a bar 600 feet below the station, and the movements of the boat affect the measurements.

Discharge measurements are made by means of a boat held from the bridge by a one-fourth inch rope cable 400 feet long. The meter is lowered 2 feet above the bow of the boat, over a roller on a projecting plank, and is controlled by a windlass. The initial point for soundings is 400 feet below the railway bridge, opposite the center of the east pier.

A staff gage in two sections, graduated to feet and tenths, is bolted vertically to the third pier from the east end of the bridge. The lower section is graduated from zero to 10 feet. The upper section is graduated from zero to 20 feet, with its zero at the 10-foot mark of the lower section. Gage readings have been reduced to the zero of the lower section. The gage is read once each day by W. B. Sloan. A United States Geological Survey standard aluminum bench-mark tablet marked "350" is placed on the south side of the first pier from the east end of the bridge; elevation, 349.78 feet above sea level and

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42.03 feet above gage datum. A United States Coast and Geodetic Survey brass bench-mark tablet on the same pier has an elevation of 44.51 feet above the datum of the gage.

A description of this station, with gage heights and discharge data, is contained in Water-Supply Paper No. 135 of the United States Geological Survey, pages 24–25.

*Daily gage height, in feet, of Columbia River near Pasco, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.7 | 7.6 | 7.9 | 10.9 | 14.1 | 18.8 | 20.5 | 16.9 | 12.7 | 11.2 | 10.4 | 8.9 |
| 2 | 7.8 | 7.4 | 8.0 | 10.9 | 13.9 | 19.4 | 20.3 | 16.9 | 12.5 | 11.3 | 10.3 | 8.9 |
| 3 | 7.8 | 7.3 | 8.1 | 10.8 | 13.8 | 20.0 | 20.1 | 16.9 | 12.3 | 11.3 | 10.2 | 8.9 |
| 4 | 7.8 | 7.3 | 8.4 | 10.8 | 13.9 | 20.7 | 20.0 | 16.8 | 12.2 | 11.5 | 10.1 | 8.8 |
| 5 | 7.7 | 7.2 | 8.7 | 10.7 | 13.9 | 21.2 | 19.8 | 16.7 | 12.0 | 11.8 | 10.0 | 8.7 |
| 6 | 7.7 | 7.2 | 9.0 | 10.6 | 14.0 | 21.6 | 19.6 | 16.6 | 11.9 | 11.9 | 10.0 | 8.7 |
| 7 | 7.6 | 7.0 | 9.2 | 10.5 | 14.0 | 21.9 | 19.4 | 16.6 | 11.7 | 12.1 | 9.9 | 8.6 |
| 8 | 7.6 | 6.8 | 9.3 | 10.5 | 14.0 | 22.1 | 19.2 | 16.6 | 11.6 | 12.2 | 9.8 | 8.6 |
| 9 | 7.6 | 6.8 | 9.5 | 10.7 | 14.2 | 22.4 | 19.1 | 16.6 | 11.3 | 12.3 | 9.7 | 8.6 |
| 10 | 7.5 | 6.9 | 9.6 | 10.8 | 14.7 | 22.8 | 19.1 | 16.5 | 11.3 | 12.4 | 9.6 | 8.6 |
| 11 | 7.4 | 7.0 | 9.8 | 11.0 | 15.3 | 23.0 | 19.0 | 16.4 | 11.2 | 12.3 | 9.5 | 8.5 |
| 12 | 7.3 | 6.7 | 10.0 | 10.9 | 15.5 | 23.2 | 19.0 | 16.3 | 11.2 | 12.1 | 9.5 | 8.4 |
| 13 | 7.3 | 6.4 | 10.2 | 10.9 | 15.6 | 23.3 | 18.9 | 16.2 | 11.2 | 12.1 | 9.5 | 8.3 |
| 14 | 7.2 | 6.5 | 10.2 | 10.9 | 15.6 | 23.4 | 18.9 | 16.1 | 11.1 | 12.0 | 9.4 | 8.2 |
| 15 | 7.1 | 6.3 | 10.2 | 10.9 | 15.6 | 23.4 | 18.9 | 16.0 | 11.1 | 11.9 | 9.3 | 8.2 |
| 16 | 7.0 | 6.2 | 10.3 | 10.9 | 15.6 | 23.3 | 18.5 | 15.9 | 11.0 | 11.8 | 9.2 | 8.2 |
| 17 | 6.9 | 6.4 | 10.2 | 10.9 | 15.6 | 23.0 | 18.4 | 15.8 | 11.0 | 11.7 | 9.2 | 8.1 |
| 18 | 6.8 | 6.5 | 10.2 | 11.0 | 15.8 | 22.9 | 18.2 | 15.7 | 10.9 | 11.5 | 9.1 | 8.1 |
| 19 | 6.9 | 6.6 | 10.4 | 11.1 | 16.1 | 22.6 | 18.1 | 15.6 | 10.9 | 11.3 | 9.1 | 8.1 |
| 20 | 7.0 | 6.7 | 10.5 | 11.2 | 16.3 | 22.4 | 18.0 | 15.1 | 10.9 | 11.1 | 9.0 | 8.1 |
| 21 | 7.0 | 6.7 | 10.6 | 11.4 | 16.6 | 22.2 | 17.9 | 15.0 | 10.8 | 11.2 | 9.0 | 8.0 |
| 22 | 7.1 | 6.8 | 10.7 | 11.7 | 16.8 | 22.0 | 17.5 | 14.9 | 10.8 | 11.1 | 9.0 | 8.0 |
| 23 | 7.1 | 7.2 | 10.8 | 12.0 | 16.9 | 22.8 | 17.3 | 14.6 | 10.7 | 11.0 | 9.0 | 8.0 |
| 24 | 7.2 | 7.4 | 10.8 | 12.3 | 16.9 | 21.6 | 17.1 | 14.3 | 10.6 | 10.9 | 9.0 | 7.9 |
| 25 | 7.3 | 7.4 | 10.9 | 12.6 | 16.9 | 21.5 | 17.0 | 13.9 | 10.6 | 10.7 | 9.0 | 7.9 |
| 26 | 7.5 | 7.5 | 10.9 | 13.2 | 16.9 | 21.4 | 16.9 | 13.8 | 10.5 | 10.7 | 8.9 | 7.8 |
| 27 | 7.7 | 7.7 | 11.0 | 13.8 | 16.9 | 21.3 | 16.9 | 13.6 | 10.7 | 10.7 | 8.9 | 7.8 |
| 28 | 7.7 | 7.8 | 11.0 | 14.3 | 17.0 | 21.0 | 16.9 | 13.4 | 10.8 | 10.8 | 8.9 | 7.8 |
| 29 | 7.7 | ..... | 11.0 | 14.4 | 17.5 | 20.8 | 16.9 | 13.2 | 10.9 | 10.8 | 8.9 | 7.8 |
| 30 | 7.8 | ..... | 11.0 | 14.3 | 17.9 | 20.7 | 16.9 | 13.0 | 10.9 | 10.7 | 8.9 | 7.7 |
| 31 | 7.7 | ..... | 10.9 | ..... | 18.3 | ..... | 16.9 | 12.9 | ..... | 10.6 | ..... | 7.7 |

NOTE.—No ice record.

## CLARK FORK DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Clark Fork of the Columbia has its source in Silverbow County, Mont., and flows northward until it receives the waters of Little Blackfoot River, when it takes a more northwesterly course. The name Missoula is usually applied to that portion of the river between the junction of Big Blackfoot and Hellgate rivers and the mouth of Flathead River. From that point to its junction with Columbia River it is called Clark Fork of the Columbia.

The source of Bitterroot River is in the high mountains which form the boundary line between Montana and Idaho. It flows in a northerly direction, entering Missoula River a short distance below the city of Missoula. The tributaries on the east side drain comparatively low hills and contribute little to the supply of the river. The west-side branches, on the contrary, are numerous, draining a precipitous and heavily wooded area. Their discharge is regulated by many small lakes, fed by banks of snow, which continue far into summer before disappearing altogether. From Hamilton to Missoula, a distance of 48 miles, the fall of the river is 350 feet, or 7.3 feet to the mile.

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### CLARK FORK[a] AT PRIEST RIVER, IDAHO.

This station was established in June, 1903, by T. A. Noble, and was discontinued April 30, 1905. It is located on the right bank of the river, about 1,000 feet west of Priest River railroad station.

The channel is straight for about 2,000 feet above and below the station. The right bank is high, covered with underbrush, and not subject to overflow. The left bank is low, cleared, and liable to overflow. From the top of the left bank there is an upward slope of about 10 per cent. The water flows in one channel, and the bed of the stream is composed of sand, with occasional bowlders.

Discharge measurements were made from a ferry cable, which is at a right angle to the stream. The initial point for soundings is a stake on the left bank of the stream and the west side of the driveway. Its elevation is 2,062.11 feet above sea level. On the right bank, 1,020 feet from the initial point, is another stake, with a tack in its head. Its elevation above sea level is 2,076.31 feet.

A wire gage is fastened to the railing of the platform, which is built between four trees. The bench marks are as follows: (1) A United States Geological Survey bench mark south of Priest River station, at the northeast corner of the hotel, from which all elevations were obtained; elevation, 2,077.00 feet; (2) a bench mark under the gage-board platform; elevation, 2,066.19 feet; (3) a bench mark on a stump near the gage; elevation, 2,073.02 feet. Elevations refer to sea level.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp. 399–400; 135, pp. 40–41.
Discharge: 100, p. 400; 135, p. 41.
Discharge, monthly: 135, p. 43.
Gage heights: 100, pp. 400–401; 135, pp. 41–42.
Rating table: 135, p. 42.

*Discharge measurements of Clark Fork at Priest River, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| January 19 | Laurgaard and Costeel | 715 | 3,896 | 2.02 | 42.52 | 7,852 |
| February 3[a] | C. Costeel | 704 | 3,498 | 1.55 | 41.85 | 5,419 |

[a] Ice conditions.

*Daily gage height, in feet, of Clark Fork at Priest River, Idaho, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | Day. | Jan. | Feb. | Mar. | Apr. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 42.68 | 42.15 | 42.72 | 43.78 | 17 | 42.42 | 42.31 | 43.2 | 43.9 |
| 2 | 42.67 | 41.3 | 42.78 | 43.75 | 18 | 42.5 | 42.3 | 43.28 | 43.9 |
| 3 | 42.72 | 41.85 | 42.8 | 43.74 | 19 | 42.52 | 42.29 | 43.31 | 43.92 |
| 4 | 42.68 | 42.22 | 42.88 | 43.8 | 20 | 42.55 | 42.32 | 43.33 | 43.92 |
| 5 | 42.7 | 42.34 | 42.9 | 43.75 | 21 | 42.57 | 42.41 | 43.35 | 43.95 |
| 6 | 42.69 | 42.4 | 42.92 | 43.69 | 22 | 42.59 | 42.42 | 43.45 | 44.01 |
| 7 | 42.8 | 42.49 | 43.0 | 43.68 | 23 | 42.6 | 42.48 | 43.5 | 44.1 |
| 8 | 42.71 | 42.45 | 43.05 | 43.68 | 24 | 42.62 | 42.52 | 43.52 | 44.19 |
| 9 | 42.62 | 42.5 | 43.09 | 43.77 | 25 | 42.65 | 42.55 | 43.6 | 44.35 |
| 10 | 42.62 | 42.75 | 43.19 | 43.7 | 26 | 42.62 | 42.6 | 43.55 | 44.27 |
| 11 | 42.54 | 41.69 | 43.35 | 43.71 | 27 | 42.68 | 42.64 | 43.63 | 44.55 |
| 12 | 41.59 | 42.0 | 43.39 | 43.77 | 28 | 42.7 | 42.69 | 43.7 | 44.75 |
| 13 | 41.12 | 42.12 | 43.32 | 43.9 | 29 | 42.73 | ..... | 43.71 | 44.9 |
| 14 | 41.24 | 42.29 | 43.15 | 43.85 | 30 | 42.71 | ..... | 43.73 | 45.01 |
| 15 | 42.04 | 42.28 | 43.19 | 43.85 | 31 | 42.8 | ..... | 43.77 | ..... |
| 16 | 42.32 | 42.3 | 43.19 | 43.89 | | | | | |

[a] Formerly called Pend Oreille River.

NOTE.—No ice record.

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*Station rating table for Clark Fork at Priest River, Idaho, from June 26, 1903, to April 30, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 41.10 | 5,680 | 42.20 | 6,990 | 43.20 | 9,740 | 44.20 | 13,470 |
| 41.20 | 5,770 | 42.30 | 7,220 | 43.30 | 10,070 | 44.30 | 13,890 |
| 41.30 | 5,865 | 42.40 | 7,460 | 43.40 | 10,410 | 44.40 | 14,320 |
| 41.40 | 5,960 | 42.50 | 7,700 | 43.50 | 10,750 | 44.50 | 14,760 |
| 41.50 | 6,055 | 42.60 | 7,960 | 43.60 | 11,110 | 44.60 | 15,200 |
| 41.60 | 6,150 | 42.70 | 8,230 | 43.70 | 11,480 | 44.70 | 15,650 |
| 41.70 | 6,250 | 42.80 | 8,510 | 43.80 | 11,860 | 44.80 | 16,110 |
| 41.80 | 6,350 | 42.90 | 8,810 | 43.90 | 12,250 | 44.90 | 16,570 |
| 41.90 | 6,450 | 43.00 | 9,110 | 44.00 | 12,650 | 45.00 | 17,050 |
| 42.00 | 6,550 | 43.10 | 9,420 | 44.10 | 13,050 | 45.99 | 21,530 |
| 42.10 | 6,770 | | | | | | |

NOTE.—The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903-1905. It is well defined above gage height 42.5 feet.

*Estimated monthly discharge of Clark Fork at Priest River, Idaho, for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 8,510 | 5,398 | 7,791 | 479,000 |
| February | 8,370 | 5,865 | 7,316 | 406,300 |
| March | 11,750 | 8,286 | 10,030 | 616,700 |
| April | 17,100 | 11,400 | 12,700 | 755,700 |

## MISSOULA RIVER AT MISSOULA, MONT.

This station was established July 10, 1898, at Higgins Avenue Bridge, Missoula, Mont. Because of fluctuations in the water surface, the station was removed May 27, 1899, to the bridge of the Bitterroot Valley division of the Northern Pacific Railway, about one-half mile downstream.

Both banks are high at this point. The water is deep and the current exceedingly swift during high water. At lower stages it is comparatively sluggish. The stream bed is probably shifting.

Ordinarily there is but one channel, broken only by two large crib piers, but in time of flood some water passes through a slough 600 feet south of the bridge. The channel is considerably obstructed by rip rap and remains of old cribs and piers.

Discharge measurements are made from the downstream side of the railway bridge. The initial point for soundings is at the right end over the northwest abutment, opposite the center of the first angle block of the truss.

A standard chain gage is attached to a horizontal timber bolted to a cottonwood tree on the right bank 400 feet above the bridge; length of chain, 21.94 feet. During 1905 the gage was read twice each day by Thomas E. Westby. The bench mark is a United States Geological Survey standard iron post on the north side of Front street, about 200 feet west of McCormick street; elevation, 3,194.64 feet above sea level (Missoula datum) and 32.46 feet above the datum of the gage.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; WS=Water-Supply Paper):

Description: Ann 20, iv, pp 490–491; 21, iv, p 418; WS 28, pp 156–157; 38, pp 364-365; 51, p 432; 66, p 131; 85, p 199; 100, p 403; 135, pp 28–29.

Discharge: WS 28, p 160; 38, p 365; 51, p 432; 66, p 131; 85, p 199; 100, p 403; 135, p 29.

Discharge, monthly: Ann 20, iv, p 491; 21, iv, p 418; 22, iv, p 435; WS 75, p 198, 85, p 201, 100, p 405; 135, p 31.

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Discharge, yearly: Ann 20, iv, p 63.
Gage heights: WS 28, p 163; 38, pp 366-367; 51, p 433; 66, p 131; 85, p 200; 100, p 404; 135, p 30.
Hydrographs: Ann 21, iv, p 419; 22, iv, p 435; WS 75, p 199.
Rating tables: WS 28, p 170; 39, p 454; 52, p 522; 66, p 177; 85, p 200; 100, p 405; 135, p 31.

*Discharge measurements of Missoula River at Missoula, Mont., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 17 | L. R. Stockman | 163 | 757 | 1.74 | 3.16 | 1,320 |
| May 5 | J. H. Sloan | 169 | 860 | 2.05 | 3.50 | 1,766 |
| May 22 | do | 184 | 1,015 | 3.89 | 4.66 | 3,950 |
| June 16 | do | 283 | 1,236 | 4.06 | 5.44 | 5,016 |
| July 10 | do | 170 | 918 | 2.52 | 4.00 | 2,310 |
| August 11 | do | 163 | 778 | 1.52 | 3.00 | 1,181 |
| September 5 | do | 158 | 665 | 1.34 | 2.56 | 888 |
| October 3 | do | 154 | 673 | 1.35 | 2.67 | 907 |
| October 24 | Morse and Sloan | 164 | 764 | 1.65 | 2.95 | 1,221 |

*Daily gage height, in feet, of Missoula River at Missoula, Mont., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 2.65 | 3.7 | 3.1 | 3.5 | 5.3 | 5.02 | 3.38 | 2.58 | 2.65 | 2.78 | 2.9 |
| 2 | ..... | 2.65 | 3.45 | 3.1 | 3.5 | 5.48 | 4.95 | 3.3 | 2.55 | 2.65 | 3.0 | 2.95 |
| 3 | ..... | 2.65 | 3.38 | 3.1 | 3.5 | 5.72 | 4.9 | 3.3 | 2.55 | 2.75 | 2.95 | 2.95 |
| 4 | ..... | 2.65 | 3.42 | 3.1 | 3.45 | 5.75 | 4.78 | 3.3 | 2.55 | 2.75 | 2.95 | 2.95 |
| 5 | ..... | 2.7 | 3.4 | 3.05 | 3.45 | 5.8 | 4.7 | 3.25 | 2.55 | 2.75 | 2.98 | 2.95 |
| 6 | ..... | 2.85 | 3.4 | 3.08 | 3.35 | 5.92 | 4.55 | 3.2 | 2.52 | 2.7 | 3.0 | 2.92 |
| 7 | 2.75 | 2.92 | 3.35 | 3.15 | 3.35 | 6.16 | 4.35 | 3.12 | 2.45 | 2.7 | 3.0 | 2.9 |
| 8 | ..... | 3.0 | 3.32 | 3.2 | 3.42 | 6.45 | 4.22 | 3.08 | 2.45 | 2.75 | 3.0 | 2.92 |
| 9 | ..... | 3.02 | 3.25 | 3.2 | 3.8 | 6.4 | 4.12 | 3.02 | 2.42 | 2.82 | 2.98 | 2.95 |
| 10 | ..... | 3.05 | 3.15 | 3.2 | 4.1 | 6.35 | 4.05 | 3.0 | 2.55 | 2.8 | 2.95 | 2.95 |
| 11 | ..... | 3.1 | 3.02 | 3.12 | 4.05 | 6.18 | 3.98 | 3.0 | 2.55 | 2.8 | 2.95 | 2.95 |
| 12 | ..... | 3.1 | 2.95 | 3.1 | 4.05 | 6.05 | 3.85 | 2.95 | 2.55 | 2.8 | 2.95 | 2.95 |
| 13 | ..... | 3.05 | 2.95 | 3.18 | 4.0 | 5.95 | 3.8 | 2.9 | 2.52 | 2.8 | 2.95 | 2.95 |
| 14 | 3.8 | 3.05 | 3.05 | 3.25 | 3.95 | 5.95 | 3.7 | 2.88 | 2.5 | 2.75 | 2.95 | 2.95 |
| 15 | ..... | 3.05 | 3.18 | 3.2 | 3.95 | 5.7 | 3.62 | 2.85 | 2.5 | 2.8 | 2.9 | 2.95 |
| 16 | ..... | 3.1 | 3.25 | 3.12 | 3.9 | 5.48 | 3.55 | 2.85 | 2.5 | 2.8 | 2.85 | 2.95 |
| 17 | ..... | 3.1 | 3.25 | 3.1 | 4.0 | 4.92 | 3.5 | 2.9 | 2.5 | 2.8 | 2.85 | 2.95 |
| 18 | ..... | 3.1 | 3.25 | 3.15 | 4.22 | 5.12 | 3.5 | 2.95 | 2.5 | 2.85 | 2.85 | 2.95 |
| 19 | ..... | 3.15 | 3.25 | 3.18 | 4.38 | 4.92 | 3.5 | 2.88 | 2.5 | 2.85 | 2.85 | 2.98 |
| 20 | ..... | 3.25 | 3.25 | 3.32 | 4.5 | 4.8 | 3.42 | 2.82 | 2.5 | 2.85 | 2.9 | 3.0 |
| 21 | 3.6 | 3.2 | 3.2 | 3.3 | 4.6 | 4.7 | 3.35 | 2.8 | 2.55 | 2.9 | 2.95 | 3.0 |
| 22 | ..... | 3.3 | 3.2 | 3.3 | 4.78 | 4.52 | 3.32 | 2.78 | 2.55 | 2.95 | 2.95 | 3.0 |
| 23 | ..... | 3.38 | 3.2 | 3.35 | 4.7 | 4.75 | 3.28 | 2.62 | 2.55 | ..... | 2.95 | 3.0 |
| 24 | ..... | 3.52 | 3.15 | 3.42 | 4.68 | 4.98 | 3.25 | 2.65 | 2.5 | ..... | 2.95 | 3.0 |
| 25 | ..... | 3.6 | 3.1 | 3.5 | 4.48 | 5.05 | 3.22 | 2.65 | 2.5 | ..... | 2.95 | 3.1 |
| 26 | 3.3 | 3.75 | 3.1 | 3.58 | 4.38 | 5.05 | 3.2 | 2.65 | 2.5 | 3.1 | 2.95 | 3.1 |
| 27 | 3.2 | 4.0 | 3.1 | 3.6 | 4.4 | 5.68 | 3.28 | 2.65 | 2.52 | 3.05 | 2.92 | 3.1 |
| 28 | 3.25 | 3.92 | 3.15 | 3.58 | 4.42 | 5.55 | 3.35 | 2.65 | 2.6 | 3.0 | 2.9 | 3.1 |
| 29 | 3.2 | ..... | 3.15 | 3.5 | 4.5 | 5.38 | 3.35 | 2.65 | 2.6 | 3.0 | 2.85 | 3.1 |
| 30 | 3.28 | ..... | 3.12 | 3.5 | 4.5 | 5.2 | 3.65 | 2.65 | 2.65 | 2.95 | 2.7 | 3.15 |
| 31 | 3.3 | ..... | 3.1 | ..... | 4.98 | ..... | 3.42 | 2.6 | ..... | 2.88 | ..... | 3.15 |

NOTE.—River frozen during January and February, March 12-13, and November 24 to December 31; readings are to top of ice.

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*Station rating table for Missoula River at Missoula, Mont., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.40 | 735 | 3.30 | 1,485 | 4.20 | 2,570 | 5.00 | 4,050 |
| 2.50 | 800 | 3.40 | 1,590 | 4.30 | 2,720 | 5.20 | 4,510 |
| 2.60 | 870 | 3.50 | 1,700 | 4.40 | 2,880 | 5.40 | 5,000 |
| 2.70 | 945 | 3.60 | 1,810 | 4.50 | 3,050 | 5.60 | 5,530 |
| 2.80 | 1,025 | 3.70 | 1,930 | 4.60 | 3,230 | 5.80 | 6,100 |
| 2.90 | 1,110 | 3.80 | 2,050 | 4.70 | 3,420 | 6.00 | 6,710 |
| 3.00 | 1,200 | 3.90 | 2,170 | 4.80 | 3,620 | 6.20 | 7,370 |
| 3.10 | 1,290 | 4.00 | 2,300 | 4.90 | 3,830 | 6.40 | 8,110 |
| 3.20 | 1,385 | 4.10 | 2,430 | | | | |

The above table is applicable only for open-channel conditions. It is based on 15 discharge measurements made during 1904–5. It is fairly well defined throughout.

*Estimated monthly discharge of Missoula River at Missoula, Mont., for 1905.*

[Drainage area, 5,960 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| March 1–11, 14–31 | 1,930 | 1,218 | 1,427 | 82,080 | 0.239 | 0.258 |
| April | 1,810 | 1,245 | 1,442 | 85,800 | .242 | .270 |
| May | 4,006 | 1,538 | 2,497 | 153,500 | .419 | .483 |
| June | 8,310 | 3,086 | 5,429 | 323,000 | .911 | 1.02 |
| July | 4,096 | 1,385 | 2,182 | 134,200 | .366 | .422 |
| August | 1,569 | 870 | 1,132 | 69,600 | .190 | .219 |
| September | 908 | 748 | 819 | 48,730 | .137 | .153 |
| October | 1,290 | 908 | 1,069 | 65,730 | .179 | .206 |
| November 1–23 | 1,200 | 1,009 | 1,140 | 52,000 | .191 | .163 |
| The period | | | | 1,015,000 | | |

NOTE.—No estimate for ice period.

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## BIG BLACKFOOT RIVER NEAR BONNER, MONT.

This station was established in July, 1898. It is situated a short distance above the junction of Big Blackfoot with Hellgate River, at the county highway bridge, one-half mile west of Bonner and 6 miles east of Missoula. The station was abandoned October 31, 1905, because of a dam which was being erected in Hellgate River just below the mouth of the Big Blackfoot.

The power dam of the Big Blackfoot Milling Company, about 1,000 yards above the station, interferes with the natural flow of the water, the opening and closing of the gates causing abrupt changes in river height. The channel at the station is straight for some distance. Both banks are high and rocky and are covered with brush and trees. Neither bank is subject to overflow. The bed of the stream is rocky and covered with cobble and bowlders. It is not liable to change. The depth of the water varies from 4 to 10 feet. The current is very swift and a stay line is necessary for the meter at all but the lowest stages.

Discharge measurements are made from the lower side of the bridge, the initial point for soundings being at the left bank.

A standard chain gage is attached to the downstream guard rail of the bridge; length of chain, 20.68 feet. During 1905 the gage was read twice each day by Charles Anderson. Bench marks were established as follows: (1) A temporary bench mark of the topographic division of the United States Geological Survey, consisting of a cross cut in the northeast corner of the top of the northeast abutment of the Northern Pacific Railway bridge near Bonner; elevation, 3,290.30 feet above sea level. (2) A standard United States Geological Survey iron post located in front of John McCormick's house just east of the highway bridge; elevation, 3,246.04 feet above sea level. The zero of the gage is 3,230.70 feet above sea level. All elevations refer to the Missoula datum.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; WS=Water-Supply Paper):

Description: Ann 20, iv, p 491; WS 28, pp 155–156; 38, p 362; 51, p 430; 66, p 130; 100, pp 410–411; 135, p 32.
Discharge: WS 28, p 168; 38, p 362; 51, p 430; 66, p 130; 85, p 216; 100, p 411; 135, p 33.
Discharge, monthly: Ann 20, iv, p 491; 21, iv, p 416; 22, iv, p 433; WS 75, p 198; 100, p 413; 135, p 34.
Discharge, yearly: Ann 20, iv, p 62.
Gage heights: WS 28, p 163; 38, p 363; 51, p 431; 66, p 130; 100, pp 411–412; 135, p 33.
Hydrographs: Ann 21, iv, p 416; 22, iv, p 434.
Rating tables: WS 28, p 170; 39, p 454; 52, p 522; 66, p 177; 100, p 412; 135, p 34.

*Discharge measurements of Big Blackfoot River near Bonner, Mont., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 17 | L. R. Stockman | 120 | 428 | 1.14 | 0.30 | 486 |
| May 5 | J. H. Sloan | 120 | 445 | 1.55 | .46 | 690 |
| May 22 | do | 127 | 614 | 3.15 | 2.04 | 1,936 |
| June 16 | do | 133 | 677 | 4.07 | 2.80 | 2,754 |
| July 10 | do | 125 | 565 | 2.26 | 1.32 | 1,278 |
| August 10 | do | 121 | 460 | 1.46 | .60 | 673 |
| September 5 | do | 119 | 405 | 1.06 | .36 | 432 |
| October 3 | do | 119 | 405 | 1.08 | .35 | 438 |
| October 24 | Morse and Sloan | 118 | 415 | 1.02 | .21 | 425 |

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*Daily gage height, in feet, of Big Blackfoot River near Bonner, Mont., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.75 | 2.3 | 1.0 | 0.2 | 0.7 | 2.8 | 1.9 | 0.7 | 0.3 | 0.3 |
| 2 | .6 | 1.95 | .7 | .2 | .8 | 3.05 | 1.8 | .75 | .25 | .4 |
| 3 | .45 | 1.85 | .55 | .25 | .75 | 3.25 | 1.8 | .75 | .25 | .35 |
| 4 | .4 | 2.2 | .45 | .25 | .8 | 3.4 | 1.7 | .7 | .3 | .3 |
| 5 | .25 | 2.1 | .45 | .15 | .7 | 3.55 | 1.6 | .7 | .25 | .25 |
| 6 | .3 | 2.2 | .45 | .2 | .7 | 3.85 | 1.55 | .7 | .25 | .3 |
| 7 | .45 | 2.1 | .35 | .25 | .75 | 3.8 | 1.5 | .65 | .25 | .3 |
| 8 | .6 | 2.2 | .35 | .25 | .8 | 3.75 | 1.4 | .6 | .25 | .25 |
| 9 | 1.2 | 2.4 | .3 | .25 | 1.0 | 3.85 | 1.35 | .6 | .1 | .35 |
| 10 | .75 | 2.35 | .35 | .25 | 1.35 | 3.75 | 1.3 | .6 | .15 | .3 |
| 11 | .7 | 2.35 | .25 | .25 | 1.3 | 3.5 | 1.25 | .6 | .15 | .4 |
| 12 | ..... | 2.05 | .05 | .25 | 1.3 | 3.3 | 1.2 | .5 | .15 | .4 |
| 13 | ..... | 2.5 | .2 | .25 | 1.3 | 3.35 | 1.15 | .5 | .2 | .3 |
| 14 | ..... | 2.6 | .25 | .2 | 1.25 | 3.25 | 1.1 | .5 | .25 | .4 |
| 15 | ..... | 2.8 | .25 | .25 | 1.2 | 3.0 | 1.05 | .5 | .25 | .35 |
| 16 | ..... | 2.6 | .2 | .2 | 1.2 | 2.8 | 1.0 | .5 | .15 | .45 |
| 17 | ..... | 2.65 | .25 | .22 | 1.2 | 2.6 | 1.0 | .5 | .2 | .35 |
| 18 | ..... | 2.4 | .25 | .3 | 1.45 | 2.5 | 1.0 | .5 | .2 | .5 |
| 19 | ..... | 2.3 | .2 | .25 | 1.65 | 2.4 | 1.0 | .5 | .25 | .4 |
| 20 | ..... | 2.35 | .3 | .3 | 1.75 | 2.25 | .9 | .5 | .2 | .45 |
| 21 | ..... | 2.15 | .35 | .3 | 1.85 | 2.1 | .9 | .4 | .15 | .4 |
| 22 | ..... | 2.25 | .3 | .3 | 2.0 | 2.1 | .9 | .4 | .15 | .15 |
| 23 | ..... | 2.05 | .25 | .3 | 1.85 | 2.2 | .8 | .4 | .15 | .3 |
| 24 | ..... | 1.6 | .2 | .35 | 1.75 | 2.2 | .8 | .3 | .15 | .4 |
| 25 | ..... | 1.4 | .2 | .4 | 1.65 | 2.1 | .8 | .3 | .2 | .4 |
| 26 | .55 | 1.45 | .25 | .6 | 1.7 | 2.15 | .8 | .3 | .35 | .35 |
| 27 | .4 | 1.3 | .25 | .65 | 1.7 | 2.25 | .8 | .3 | .3 | .3 |
| 28 | .3 | 1.3 | .25 | .75 | 1.75 | 2.15 | .85 | .3 | .35 | .35 |
| 29 | .15 | ..... | .25 | .7 | 1.85 | 2.05 | .9 | .3 | .3 | .25 |
| 30 | .2 | ..... | .2 | .7 | 2.2 | 1.9 | .8 | .3 | .4 | .25 |
| 31 | .4 | ..... | .2 | ..... | 2.5 | ..... | .8 | .3 | ..... | .25 |

NOTE.—River frozen January 12-25, also February 1-28. Readings to top of ice. Ice gorge below station during February.

*Station rating table for Big Blackfoot River near Bonner, Mont., from January 1 to October 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.10 | 340 | 1.10 | 1,030 | 2.10 | 1,970 | 3.10 | 3,150 |
| 0.20 | 390 | 1.20 | 1,120 | 2.20 | 2,080 | 3.20 | 3,290 |
| 0.30 | 440 | 1.30 | 1,210 | 2.30 | 2,190 | 3.30 | 3,430 |
| 0.40 | 500 | 1.40 | 1,300 | 2.40 | 2,300 | 3.40 | 3,590 |
| 0.50 | 560 | 1.50 | 1,390 | 2.50 | 2,420 | 3.50 | 3,750 |
| 0.60 | 630 | 1.60 | 1,480 | 2.60 | 2,540 | 3.60 | 3,910 |
| 0.70 | 700 | 1.70 | 1,570 | 2.70 | 2,660 | 3.70 | 4,090 |
| 0.80 | 770 | 1.80 | 1,660 | 2.80 | 2,780 | 3.80 | 4,270 |
| 0.90 | 850 | 1.90 | 1,760 | 2.90 | 2,900 | 3.90 | 4,450 |
| 1.00 | 940 | 2.00 | 1,860 | 3.00 | 3,020 | 4.00 | 4,630 |

NOTE.—The above table is applicable only for open-channel conditions. It is based on 17 discharge measurements made during 1904-1905, and is fairly well defined throughout.

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*Estimated monthly discharge of Big Blackfoot River near Bonner, Mont., for 1905.*

[Drainage area, 2,465 square miles.]

| Month | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January 1-11, 27-31 | 1,120 | 365 | 572 | 18,150 | 0.232 | 0.138 |
| March | 940 | 320 | 459 | 28,220 | .186 | .214 |
| April | 735 | 365 | 463 | 27,550 | .188 | .210 |
| May | 2,420 | 700 | 1,294 | 79,560 | .525 | .605 |
| June | 4,360 | 1,760 | 2,936 | 174,700 | 1.19 | 1.33 |
| July | 1,760 | 770 | 1,079 | 66,350 | .437 | .504 |
| August | 735 | 440 | 565 | 34,740 | .229 | .264 |
| September | 500 | 340 | 407 | 24,220 | .165 | .184 |
| October | 560 | 365 | 465 | 28,590 | .189 | .218 |
| The period | | | | 482,100 | | |

NOTE.—No estimate for ice period.

## BITTERROOT RIVER NEAR GRANTSDALE, MONT.

This station was established April 25, 1902. It is located on the highway bridge 2 miles southwest of Grantsdale and 5 miles southwest of Hamilton, Mont. Two large ditches—the New Hedge and the Republican—are taken out of the river some distance above the station. They irrigate extensive farm lands and orchards in the vicinity of Hamilton.

The channel is straight both above and below the station. The stream has a moderate velocity at ordinary stages, but is extremely swift in high water. The right bank has a gentle slope for about 100 feet, when it terminates at a high bank which is not liable to overflow. The left bank is high and formed above the bridge by a railway fill. The bed of the stream is composed of gravel and bowlders.

Discharge measurements are made from the downstream side of the highway bridge, with the aid of a stay wire. The initial point for soundings is a notch on the hand rail over the northwest bridge pier at the left bank.

A standard chain gage is fastened to the downstream truss of the bridge; length of chain, 23.33 feet. During 1905 the gage was read once each day by T. J. Holt. Bench marks were established as follows: (1) A wire nail driven in the northeast side of a pine stump across the road from the west end of the bridge; elevation, 24.40 feet. (2) The northwest bolt in the northwest abutment plate of the bridge; elevation, 19.36 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 85, p 201; 100, p 408; 135, p 35.
Discharge: 85, p 202; 100, p 408; 135, p 35.
Discharge, monthly: 85, p 203; 100, p 410; 135, p 37.
Gage heights: 85, p 202; 100, p 409; 135, p 36.
Rating tables: 85, p 203; 100, p 409; 135, p 36.

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*Discharge measurements of Bitterroot River near Grantsdale, Mont., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 18 | Stockman and Sloan | 170 | 412 | 1.73 | 2.22 | 713 |
| May 6 | J. H. Sloan | 170 | 420 | 2.17 | 2.42 | 910 |
| May 23 | do | 182 | 562 | 3.43 | 3.22 | 1,920 |
| June 17 | do | 183 | 588 | 3.85 | 3.50 | 2,265 |
| July 11 | do | 183 | 516 | 2.63 | 2.88 | 1,356 |
| August 11 | do | 168 | 268 | .75 | 1.51 | 200 |
| September 6 | do | 156 | 221 | .33 | 1.21 | 70 |
| October 4 | do | 168 | 259 | .64 | 1.46 | 167 |
| October 25 | Morse and Sloan | 168 | 298 | 1.06 | 1.70 | 315 |

*Daily gage height, in feet, of Bitterroot River near Grantsdale, Mont., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.85 | 1.95 | 1.65 | 1.75 | 2.8 | 4.3 | 3.6 | 1.8 | 1.2 | 1.5 | 1.6 | 1.6 |
| 2 | 1.85 | 1.95 | 1.65 | 1.75 | 2.7 | 4.5 | 3.5 | 1.8 | 1.2 | 1.5 | 1.6 | 1.6 |
| 3 | 1.75 | 1.95 | 1.75 | 1.75 | 2.6 | 4.6 | 3.4 | 1.8 | 1.2 | 1.5 | 1.6 | 1.6 |
| 4 | 1.75 | 1.95 | 1.75 | 1.75 | 2.5 | 4.6 | 3.4 | 1.7 | 1.2 | 1.4 | 1.6 | 1.6 |
| 5 | 1.75 | 1.95 | 1.85 | 1.95 | 2.4 | 4.5 | 3.3 | 1.7 | 1.3 | 1.4 | 1.6 | 1.6 |
| 6 | 1.65 | 1.95 | 1.85 | 1.95 | 2.4 | 4.3 | 3.2 | 1.7 | 1.3 | 1.4 | 1.6 | 2.0 |
| 7 | 1.65 | 1.95 | 1.95 | 2.15 | 2.5 | 4.2 | 3.0 | 1.6 | 1.2 | 1.4 | 1.6 | 2.0 |
| 8 | 1.65 | 2.05 | 1.95 | 2.15 | 2.6 | 4.3 | 2.9 | 1.6 | 1.2 | 1.4 | 1.5 | 1.9 |
| 9 | 1.65 | 2.05 | 1.95 | 2.25 | 2.8 | 4.9 | 2.9 | 1.5 | 1.2 | 1.5 | 1.5 | 2.1 |
| 10 | 1.85 | 2.15 | 1.95 | 2.25 | 2.9 | 4.5 | 2.8 | 1.5 | 1.2 | 1.5 | 1.5 | 2.1 |
| 11 | 1.95 | 2.15 | 1.95 | 2.15 | 2.8 | 4.5 | 2.8 | 1.4 | 1.2 | 1.5 | 1.5 | 2.1 |
| 12 | 1.95 | 2.25 | 1.85 | 2.15 | 2.7 | 4.4 | 2.7 | 1.4 | 1.2 | 1.6 | 1.5 | 2.1 |
| 13 | 2.15 | 2.35 | 1.85 | 2.05 | 2.6 | 4.3 | 2.6 | 1.4 | 1.1 | 1.6 | 1.5 | 2.1 |
| 14 | 2.25 | 2.45 | 1.95 | 2.05 | 2.6 | 4.2 | 2.5 | 1.4 | 1.1 | 1.7 | 1.5 | 2.0 |
| 15 | 2.35 | 2.45 | 1.95 | 2.05 | 2.5 | 4.0 | 2.5 | 1.3 | 1.1 | 1.7 | 1.5 | 1.9 |
| 16 | 2.35 | 2.45 | 1.95 | 2.15 | 2.5 | 3.8 | 2.4 | 1.3 | 1.1 | 1.7 | 1.5 | 1.8 |
| 17 | 2.35 | 1.95 | 1.95 | 2.05 | 3.1 | 3.5 | 2.4 | 1.3 | 1.1 | 1.7 | 1.6 | 1.8 |
| 18 | 2.35 | 1.95 | 2.05 | 2.15 | 3.5 | 3.3 | 2.3 | 1.3 | 1.1 | 1.6 | 1.6 | 1.8 |
| 19 | 1.75 | 1.85 | 2.05 | 2.2 | 3.4 | 3.2 | 2.3 | 1.3 | 1.0 | 1.6 | 1.6 | 2.1 |
| 20 | 1.75 | 1.85 | 2.05 | 2.5 | 3.5 | 3.2 | 2.2 | 1.4 | 1.0 | 1.6 | 1.6 | 2.1 |
| 21 | 1.75 | 1.85 | 1.95 | 2.6 | 3.4 | 3.2 | 2.2 | 1.4 | 1.0 | 1.6 | 1.6 | 2.1 |
| 22 | 1.65 | 1.85 | 1.95 | 2.6 | 3.3 | 3.4 | 2.1 | 1.3 | 1.0 | 1.6 | 1.6 | 2.0 |
| 23 | 1.65 | 1.75 | 1.95 | 2.8 | 3.2 | 3.6 | 2.1 | 1.3 | 1.1 | 1.5 | 1.7 | 2.0 |
| 24 | 1.65 | 1.75 | 1.95 | 3.0 | 3.1 | 3.7 | 2.1 | 1.2 | 1.1 | 1.5 | 1.7 | 2.0 |
| 25 | 1.65 | 1.75 | 1.95 | 3.2 | 3.0 | 3.7 | 2.0 | 1.4 | 1.1 | 1.6 | 1.8 | 2.0 |
| 26 | 1.65 | 1.75 | 1.95 | 3.4 | 2.9 | 3.7 | 2.0 | 1.3 | 1.2 | 1.7 | 1.8 | 2.0 |
| 27 | 1.65 | 1.65 | 1.95 | 3.2 | 3.0 | 4.1 | 2.0 | 1.3 | 1.2 | 1.7 | 1.7 | 1.6 |
| 28 | 1.65 | 1.65 | 1.95 | 3.0 | 3.1 | 3.9 | 1.9 | 1.2 | 1.3 | 1.7 | 1.7 | 1.6 |
| 29 | 1.65 | ..... | 1.95 | 2.9 | 3.1 | 3.7 | 1.9 | 1.2 | 1.4 | 1.7 | 1.7 | 1.7 |
| 30 | 1.65 | ..... | 1.85 | 2.8 | 3.6 | 3.6 | 1.8 | 1.2 | 1.4 | 1.7 | 1.7 | 1.8 |
| 31 | 1.65 | ..... | 1.85 | ..... | 4.0 | ..... | 1.8 | 1.2 | ..... | 1.7 | ..... | 1.8 |

NOTE.—Ice conditions January 1-18, February 1-18, December 6-27. During February the ice increased from 0.3 to 0.9 foot in thickness. Readings are to top of ice.

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*Station rating table for Bitterroot River near Grantsdale, Mont., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.10 | 15 | 2.10 | 635 | 3.10 | 1,695 | 4.10 | 3,435 |
| 1.20 | 50 | 2.20 | 725 | 3.20 | 1,825 | 4.20 | 3,660 |
| 1.30 | 95 | 2.30 | 820 | 3.30 | 1,965 | 4.30 | 3,885 |
| 1.40 | 145 | 2.40 | 920 | 3.40 | 2,105 | 4.40 | 4,110 |
| 1.50 | 200 | 2.50 | 1,020 | 3.50 | 2,265 | 4.50 | 4,335 |
| 1.60 | 260 | 2.60 | 1,120 | 3.60 | 2,435 | 4.60 | 4,560 |
| 1.70 | 325 | 2.70 | 1,225 | 3.70 | 2,615 | 4.70 | 4,785 |
| 1.80 | 395 | 2.80 | 1,335 | 3.80 | 2,805 | 4.80 | 5,010 |
| 1.90 | 470 | 2.90 | 1,450 | 3.90 | 3,005 | 4.90 | 5,235 |
| 2.00 | 550 | 3.00 | 1,570 | 4.00 | 3,215 | 5.00 | 5,460 |

NOTE.—The above table is applicable only for open-channel conditions. It is based on 16 discharge measurements made during 1904–5. It is well defined throughout.

*Estimated monthly discharge of Bitterroot River near Grantsdale, Mont., for 1905.*

[Drainage area, 1,550 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January 19–31 | 392 | 360 | 385 | 9,927 | 0.248 | 0.120 |
| February 19–28 | 428 | 360 | 394 | 7,815 | .254 | .094 |
| March | 592 | 360 | 485 | 29,820 | .313 | .361 |
| April | 2,105 | 360 | 915 | 54,450 | .590 | .658 |
| May | 3,215 | 920 | 1,544 | 94,940 | .996 | 1.15 |
| June | 5,235 | 1,825 | 3,276 | 194,900 | 2.11 | 2.35 |
| July | 2,435 | 395 | 1,111 | 68,310 | .717 | .827 |
| August | 395 | 50 | 168 | 10,330 | .108 | .124 |
| September | 145 | 5 | 44 | 2,636 | .029 | .032 |
| October | 325 | 145 | 247 | 15,190 | .159 | .183 |
| November | 395 | 200 | 264 | 15,710 | .170 | .190 |
| December 1–5 | 260 | 260 | 260 | 2,578 | .168 | .031 |
| The period | | | | 506,600 | | |

NOTE.—No estimate for ice period.

## PRIEST RIVER AT PRIEST RIVER, IDAHO.

This station was established in June, 1903, by T. A. Noble, and discontinued April 30, 1905. It is located at the highway bridge on the road from the railroad station at Priest River to Priest Lake.

The channel is straight for 500 feet above and 200 feet below the bridge. Both banks are high, wooded, and not liable to overflow. Extending from each pier of the single-span bridge to the bank is a breakwater composed of piles faced with planks. These breakwaters make the current sluggish between the piers and the banks. Under the main span of the bridge, a distance of 120 feet, the current is swift. The bed of the stream is composed of gravel.

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Discharge measurements were made from the downstream side of the bridge. The initial point for soundings is the bolt, around which a circle has been painted, at the end of the guard rail at the right bank.

A vertical staff gage is nailed to a pile on the downstream side of the right pier of the bridge. During the early part of 1905 the gage was read once each day by George Young. Bench marks were established as follows: (1) The bolt in the guard rail at the west end of the bridge, which is used as initial point for soundings; elevation, 29.04 feet. (2) A spike driven into a stump under the right approach to the bridge; elevation, 17.48 feet. Elevations refer to the datum of the gage. Bench mark No. 1 is 2,079.7 feet above sea level.

January 18, 1905, a discharge measurement made at this station by Laurgaard and Casteel gave the following results: Width, 127 feet; area of section, 321 square feet; mean velocity, 2.10 feet per second; gage height, 3.22 feet; discharge, 637 second-feet. There was ice along the river banks at the time of the measurement.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p. 401; 135, pp. 43–44.
Discharge: 100, p. 402; 135, p. 44.
Discharge, monthly: 135, p. 46.
Gage heights: 100, p. 402; 135, pp. 44–45.
Rating table: 135, p. 45.

*Daily gage height, in feet, of Priest River at Priest River, Idaho, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | Day. | Jan. | Feb. | Mar. | Apr. | Day. | Jan. | Feb. | Mar. | Apr. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1..... | 3.22 | 2.9 | 3.59 | 4.68 | 12..... | 3.52 | 3.52 | 3.98 | 4.53 | 22..... | 3.26 | 3.59 | 4.59 | 4.6 |
| 2..... | 3.1 | 3.3 | 3.64 | 4.65 | 13..... | 3.9 | 3.71 | 3.97 | 4.55 | 23..... | 3.27 | 3.6 | 4.59 | 4.6 |
| 3..... | 3.22 | 3.52 | 3.74 | 4.61 | 14..... | 4.31 | 3.7 | 3.95 | 4.58 | 24..... | 3.34 | 3.62 | 4.68 | 4.7 |
| 4..... | 3.23 | 3.63 | 3.86 | 4.57 | 15..... | 3.95 | 3.62 | 3.97 | 4.6 | 25..... | 3.41 | 3.6 | 4.69 | 4.7 |
| 5..... | 3.3 | 3.45 | 3.78 | 4.54 | 16..... | 3.62 | 3.65 | 3.99 | 4.68 | 26..... | 3.45 | 3.69 | 4.68 | 4.9 |
| 6..... | 3.31 | 3.21 | 3.88 | 4.55 | 17..... | 3.43 | 3.66 | 3.99 | 4.55 | 27..... | 3.5 | 3.81 | 4.69 | 5.09 |
| 7..... | 3.3 | 3.39 | 3.91 | 4.55 | 18..... | 3.28 | 3.67 | 4.11 | 4.6 | 28..... | 3.64 | 3.61 | 4.69 | 5.11 |
| 8..... | 3.31 | 3.49 | 3.93 | 4.57 | 19..... | 3.26 | 3.61 | 4.14 | 4.52 | 29..... | 3.67 | ..... | 4.67 | 5.12 |
| 9..... | 3.15 | 3.49 | 3.97 | 4.58 | 20..... | 3.27 | 3.62 | 4.25 | 4.58 | 30..... | 3.48 | ..... | 4.68 | 5.19 |
| 10..... | 3.13 | 3.42 | 4.01 | 4.54 | 21..... | 3.27 | 3.59 | 4.51 | 4.62 | 31..... | 3.45 | ..... | 4.69 | ..... |
| 11..... | 3.05 | 3.05 | 4.03 | 4.53 | | | | | | | | | | |

NOTE.—No ice record.

## SPOKANE RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Spokane River rises in the northern part of Idaho, being an outlet of Lake Cœur d'Alene. It passes into Washington, flows in a westerly direction, and enters Columbia River near latitude 47° 52′ north. It is about 120 miles long.

### CŒUR D'ALENE LAKE AT CŒUR D'ALENE, IDAHO.

This station was established February 11, 1905, to obtain a record of the fluctuations of the lake surface, and was discontinued September 30, 1905.

A vertical staff gage is nailed to a pile in front of Rosen's boathouse, 400 feet east of the Cœur d'Alene Railroad depot. During 1905 the gage was read once each day by John C Rosen. The bench mark is a United States Geological Survey standard bench-mark tablet in the southeast corner of Wiggett & Empey Company's brick store building, 37.65 feet above the datum of the gage and 2,157.00 feet above sea level.

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*Daily gage height, in feet, of Cœur d'Alene Lake at Cœur d'Alene, Idaho, for 1905.*

| Day. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.55 | 4.25 | 5.1 | 5.15 | 3.1 | 1.05 | 0.35 |
| 2 | ..... | 1.7 | 4.2 | 5.0 | 5.15 | 3.05 | 1.0 | .3 |
| 3 | ..... | 1.8 | 4.1 | 4.85 | 5.15 | 2.95 | .95 | .3 |
| 4 | ..... | 2.0 | 4.0 | 4.75 | 5.2 | 2.9 | .95 | .3 |
| 5 | ..... | 2.2 | 3.9 | 4.65 | 5.3 | 2.8 | .9 | .3 |
| 6 | ..... | 2.4 | 3.85 | 4.4 | 5.4 | 2.65 | .85 | .3 |
| 7 | ..... | 2.6 | 3.85 | 4.4 | 5.45 | 2.55 | .8 | .3 |
| 8 | ..... | 2.7 | 3.85 | 4.3 | 5.45 | 2.5 | .8 | .25 |
| 9 | ..... | 2.8 | 3.9 | 4.35 | 5.4 | 2.4 | .75 | .25 |
| 10 | ..... | 2.9 | 4.0 | 4.6 | 5.4 | 2.3 | .7 | .25 |
| 11 | ..... | 2.95 | 4.05 | 4.7 | 5.3 | 2.2 | .7 | .25 |
| 12 | ..... | 3.0 | 4.05 | 4.85 | 5.2 | 2.15 | .65 | .2 |
| 13 | ..... | 3.05 | 4.0 | 4.95 | 5.05 | 2.05 | .65 | .2 |
| 14 | ..... | 3.05 | 4.0 | 5.0 | 4.95 | 2.0 | .6 | .2 |
| 15 | 0.85 | 3.05 | 3.9 | 5.0 | 4.8 | 1.9 | .6 | .2 |
| 16 | .85 | 3.0 | 3.9 | 5.05 | 4.65 | 1.85 | .55 | .2 |
| 17 | .8 | 3.0 | 3.85 | 5.1 | 4.5 | 1.8 | .55 | .2 |
| 18 | .75 | 3.0 | 3.85 | 5.15 | 4.35 | 1.7 | .5 | .2 |
| 19 | .8 | 3.15 | 3.9 | 5.2 | 4.2 | 1.65 | .5 | .2 |
| 20 | .8 | 3.3 | 4.0 | 5.2 | 4.05 | 1.6 | .5 | .2 |
| 21 | .8 | 3.4 | 4.15 | 5.25 | 3.9 | 1.55 | .5 | .2 |
| 22 | .8 | 3.55 | 4.3 | 5.25 | 3.8 | 1.5 | .45 | .2 |
| 23 | .9 | 3.65 | 4.4 | 5.25 | 3.75 | 1.45 | .45 | .2 |
| 24 | .95 | 3.75 | 4.55 | 5.25 | 3.6 | 1.45 | .45 | .15 |
| 25 | 1.05 | 3.85 | 4.7 | 5.25 | 3.5 | 1.35 | .4 | .15 |
| 26 | 1.2 | 4.0 | 4.9 | 5.2 | 3.45 | 1.3 | .4 | .2 |
| 27 | 1.3 | 4.15 | 5.1 | 5.2 | 3.4 | 1.25 | .4 | .25 |
| 28 | 1.45 | 4.25 | 5.25 | 5.15 | 3.35 | 1.2 | .4 | .3 |
| 29 | ..... | 4.35 | 5.25 | 5.15 | 3.25 | 1.15 | .4 | .35 |
| 30 | ..... | 4.4 | 5.15 | 5.15 | 3.15 | 1.1 | .35 | .4 |
| 31 | ..... | 4.35 | ..... | 5.15 | ..... | 1.1 | .35 | ..... |

## SPOKANE RIVER AT SPOKANE, WASH.

This gaging station was originally established October 17, 1896, by C. C. Babb, on the Oregon Railroad and Navigation Company's wooden bridge, about 1 mile above the falls, where discharge measurements and gage readings were taken until July 8, 1903, the gage datum being 1,880 feet above sea level by city datum and 1,865 feet by Government datum.

March 30, 1904, a cable station was established about one-half mile above the Mission Street Bridge, or 1 mile above the former station at the Oregon Railroad and Navigation Company's bridge. The station is equipped with a cable, stay wire, and tag wire. The section here is a good one for stream measurements; the bed is composed of gravel and small bowlders and not liable to change. The banks on both sides are high and will not overflow. The current, except at the lowest stages, is swift.

Since the date of establishing, owing to various conditions, it has been necessary to put in several gages. During 1905 a vertical gage was fastened to the inside of the most easterly pier on the south side of the Mission Street Bridge, and was used until April 17, 1905, when a new gage was erected 200 feet upstream from the cable, on the right bank. The elevation of the zero is 1,851.926 feet above sea level. From 0 to 21.6 feet the gage is an inclined section on the bank of the river; from 21.6 to 29.2 feet it is a vertical section fastened to a tree.

During 1905 the gage was read once each day, by A. C. Lingle.



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Bench marks were established as follows: (1) Top of a granite bowlder 15 feet west of the cable post on the right bank of the river, marked "B. M." cut in the stone; elevation, 30.36 feet; (2) chisel draft on a bowlder between shear poles and water's edge, elevation 27.44 feet. Elevations refer to datum of the gage, which is 1,851.93 feet above sea level.

November 24, 1905, a discharge measurement made at this station by W. C. Sawyer gave the following results: Width, 215 feet; area of section, 1,894 square feet; mean velocity, 1.11 feet per second; gage height, 1.96 feet; discharge, 2,100 second-feet.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; WS=Water-Supply Paper):

Description: Ann 18, iv, pp 359–360; 20, iv, p 510; WS 16, p 177; 28, p 159; 38, pp 370–371; 51, pp 438–439; 66, p 133; 85, pp 196–197; 100, p 396; 135, pp 46–48.
Discharge: Ann 18, iv, p 360; 19, iv, p 460; WS 16, p 177; 28, p 169; 38, p 371; 51, p 49; 135, p 48.
Discharge, monthly: Ann 19, iv, p 488; 20, iv, p 511; 21, iv, p 424; 22, iv, p 443; WS 75, p 200; 85, p 196; 135, pp 50–51.
Discharge, yearly: Ann 20, iv, p 63.
Gage heights: WS 11, p 88; 16, p 177; 28, p 166; 38, p 371; 51, p 439; 66, p 133; 85, p 197; 100, p 397; 135, p 49.
Hydrographs: Ann 19, iv, p 489; 20, iv, p 511; 21, iv, p 425; 22, iv, p 443; WS 75, p 200;
Rating tables: Ann 19, iv, p 488; WS 28, p 170; 39, p 454; 52, p 522; 66, p 177; 85, p 198; 135, p 50.

*Daily gage height, in feet, of Spokane River at Spokane, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.94 | 2.05 | 2.25 | 5.0 | 5.74 | 5.7 | 4.07 | 2.22 | 1.43 | 1.42 | 2.3 | 2.23 |
| 2 | 2.01 | 2.06 | 2.37 | 4.93 | 5.63 | 5.72 | 4.02 | 2.15 | 1.46 | 1.87 | 2.31 | 2.24 |
| 3 | 2.09 | 2.03 | 2.47 | 4.88 | 5.53 | 5.76 | 3.97 | 2.12 | 1.32 | 1.9 | 2.32 | 2.24 |
| 4 | 2.12 | 1.96 | 2.61 | 4.82 | 5.47 | 5.8 | 3.9 | 2.11 | 1.5 | 1.72 | 2.33 | 2.31 |
| 5 | 2.11 | 1.96 | 2.79 | 4.74 | 5.4 | 5.85 | 3.8 | 2.05 | 1.31 | 1.75 | 2.31 | 2.21 |
| 6 | 2.11 | 1.97 | 3.0 | 4.7 | 5.3 | 5.87 | 3.7 | 2.0 | 1.36 | 1.8 | 2.27 | 2.23 |
| 7 | 2.1 | 1.97 | 3.21 | 4.65 | 5.18 | 5.94 | 3.63 | 1.97 | 1.44 | 1.92 | 2.28 | 2.22 |
| 8 | 2.07 | 1.99 | 3.36 | 4.63 | 5.1 | 6.0 | 3.57 | 1.9 | 1.61 | 2.03 | 2.27 | 2.2 |
| 9 | 2.05 | 1.99 | 3.49 | 4.7 | 5.17 | 5.92 | 3.5 | 1.85 | 1.63 | 2.12 | 2.22 | 2.2 |
| 10 | 2.02 | 1.96 | 3.56 | 4.73 | 5.24 | 5.92 | 3.42 | 1.81 | 1.73 | 2.14 | 2.21 | 2.19 |
| 11 | 1.99 | 1.92 | 3.6 | 4.78 | 5.42 | 5.87 | 3.33 | 1.94 | 1.69 | 2.3 | 2.15 | 2.17 |
| 12 | 1.95 | 1.9 | 3.7 | 4.79 | 5.51 | 5.82 | 3.24 | 1.83 | 1.62 | 2.35 | 2.12 | 2.15 |
| 13 | 1.9 | 1.87 | 3.74 | 4.8 | 5.59 | 5.76 | 3.16 | 1.7 | 1.69 | 2.43 | 2.10 | 2.13 |
| 14 | 1.85 | 1.85 | 3.8 | 4.78 | 5.67 | 5.66 | 3.1 | 1.7 | 1.67 | 2.4 | 2.10 | 2.09 |
| 15 | 1.81 | 1.83 | 3.83 | 4.74 | 5.64 | 5.52 | 3.03 | 1.65 | 1.7 | 2.4 | 2.09 | 2.05 |
| 16 | 1.8 | 1.82 | 3.83 | 4.71 | 5.67 | 5.4 | 2.97 | 1.63 | 1.65 | 2.38 | 2.08 | 2.03 |
| 17 | 1.8 | 1.8 | 3.8 | 4.7 | 5.7 | 5.22 | 2.9 | 1.57 | 1.63 | 2.4 | 2.07 | 2.08 |
| 18 | 1.8 | 1.79 | 3.82 | 4.69 | 5.73 | 5.17 | 2.81 | 1.62 | 1.66 | 2.38 | 2.02 | 2.1 |
| 19 | 1.8 | 1.77 | 3.9 | 4.73 | 5.8 | 5.05 | 2.8 | 1.6 | 1.72 | 2.36 | 2.0 | 2.12 |
| 20 | 1.81 | 1.78 | 4.0 | 4.77 | 5.8 | 4.92 | 2.75 | 1.58 | 1.68 | 2.4 | 2.0 | 2.19 |
| 21 | 1.8 | 1.77 | 4.15 | 4.85 | 5.82 | 4.8 | 2.68 | 1.55 | 1.57 | 2.33 | 2.0 | 2.2 |
| 22 | 1.79 | 1.78 | 4.27 | 4.96 | 5.84 | 4.72 | 2.62 | 1.53 | 1.71 | 2.32 | 1.99 | 2.2 |
| 23 | 1.8 | 1.78 | 4.37 | 5.08 | 5.82 | 4.62 | 2.58 | 1.52 | 1.67 | 2.3 | 2.0 | 2.21 |
| 24 | 1.81 | 1.78 | 4.48 | 5.15 | 5.84 | 4.57 | 2.53 | 1.5 | 1.51 | 2.28 | 1.92 | 2.2 |
| 25 | 1.81 | 1.84 | 4.55 | 5.3 | 5.81 | 4.46 | 2.49 | 1.46 | 1.52 | 2.35 | 2.03 | 2.19 |
| 26 | 1.85 | 1.92 | 4.64 | 5.44 | 5.81 | 4.4 | 2.43 | 1.44 | 1.5 | 2.36 | 2.1 | 2.2 |
| 27 | 1.86 | 2.0 | 4.74 | 5.61 | 5.81 | 4.35 | 2.4 | 1.44 | 1.49 | 2.21 | 2.2 | 2.2 |
| 28 | 1.92 | 2.11 | 4.88 | 5.74 | 5.8 | 4.3 | 2.34 | 1.4 | 1.3 | 2.23 | 2.17 | 2.18 |
| 29 | 1.99 | ..... | 4.95 | 5.78 | 5.8 | 4.24 | 2.3 | 1.38 | 1.32 | 2.29 | 2.14 | 2.17 |
| 30 | 2.03 | ..... | 5.0 | 5.76 | 5.78 | 4.17 | 2.27 | 1.4 | 1.3 | 2.3 | 2.19 | 2.16 |
| 31 | 2.04 | ..... | 5.03 | ..... | 5.78 | ..... | 2.24 | 1.52 | ..... | 2.31 | ..... | 2.17 |

NOTE.—No ice record.

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*Station rating table for Spokane River at Spokane, Wash., from April 1, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.00 | 940 | 2.70 | 3,260 | 4.30 | 6,090 | 6.80 | 11,340 |
| 1.10 | 1,030 | 2.80 | 3,420 | 4.40 | 6,280 | 7.00 | 11,830 |
| 1.20 | 1,130 | 2.90 | 3,660 | 4.50 | 6,470 | 7.20 | 12,330 |
| 1.30 | 1,240 | 3.00 | 3,740 | 4.60 | 6,660 | 7.40 | 12,850 |
| 1.40 | 1,360 | 3.10 | 3,910 | 4.70 | 6,850 | 7.60 | 13,380 |
| 1.50 | 1,490 | 3.20 | 4,080 | 4.80 | 7,050 | 7.80 | 13,930 |
| 1.60 | 1,620 | 3.30 | 4,250 | 4.90 | 7,250 | 8.00 | 14,490 |
| 1.70 | 1.760 | 3.40 | 4,420 | 5.00 | 7,450 | 8.20 | 15,050 |
| 1.80 | 1,900 | 3.50 | 4,600 | 5.20 | 7,850 | 8.40 | 15,610 |
| 1.90 | 2,040 | 3.60 | 4,780 | 5.40 | 8,250 | 8.60 | 16,190 |
| 2.00 | 2,190 | 3.70 | 4,960 | 5.60 | 8,660 | 8.80 | 16,780 |
| 2.10 | 2,340 | 3.80 | 5,140 | 5.80 | 9,080 | 9.00 | 17,380 |
| 2.20 | 2,490 | 3.90 | 5,330 | 6.00 | 9,510 | 9.50 | 18,980 |
| 2.30 | 2,640 | 4.00 | 5,520 | 6.20 | 9,950 | 10.00 | 20,580 |
| 2.40 | 2,790 | 4.10 | 5,710 | 6.40 | 10,400 | 10.50 | 22,280 |
| 2.50 | 2,940 | 4.20 | 5,900 | 6.60 | 10,860 | 11.00 | 23,980 |
| 2.60 | 3.100 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on 20 discharge measurements made during 1904 and one made during 1905. It is well defined between gage heights 1.4 feet and 12 feet. Above gage height 11 feet the rating curve is a tangent, the difference being 360 per tenth.

*Estimated monthly discharge of Spokane River at Spokane, Wash., for 1905.*

[Drainage area 4,005 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 2,370 | 1,886 | 2,089 | 128,400 | 0.522 | 0.602 |
| February | 2,355 | 1,858 | 2,047 | 113,700 | .511 | .532 |
| March | 7,510 | 2,565 | 5,223 | 321,200 | 1.30 | 1.50 |
| April | 9,038 | 6,717 | 7,383 | 439,300 | 1.84 | 2.05 |
| May | 9,164 | 7,650 | 8,706 | 535,300 | 2.17 | 2.50 |
| June | 9,510 | 5,843 | 7,974 | 474,500 | 1.99 | 2.22 |
| July | 5,653 | 2,550 | 3,865 | 237,600 | .965 | 1.11 |
| August | 2,520 | 1,336 | 1,789 | 110,000 | .447 | .515 |
| September | 1,802 | 1,240 | 1,555 | 92,530 | .388 | .433 |
| October | 2,835 | 1,386 | 2,472 | 152,000 | .617 | .711 |
| November | 2,885 | 2,070 | 2,411 | 143,500 | .602 | .672 |
| December | 2,655 | 2,235 | 2,454 | 150,900 | .613 | .707 |
| The year | 9,510 | 1,240 | 3,997 | 2,899,000 | .997 | 13.55 |

## HANGMAN CREEK AT TEKOA, WASH.

This station was established April 1, 1904, by W. W. Schlecht, and discontinued September 30, 1905. It is located at the footbridge across Hangman Creek about 1,000 feet above the mouth of North Fork of Hangman Creek, in Tekoa, Wash. There is a fall of about 2½ feet between the two points.

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The channel is straight for about 75 feet above and 40 feet below the station. The current is sluggish. About 50 feet below the station is the head of a series of rapids. The right bank is fringed with brush and liable to overflow to the railroad embankment, about 50 feet. The left bank is high, steep, composed of clay, fringed with brush, and not subject to overflow. The bed of the stream is composed of solid rock with earth banks and is not liable to shift. The station may at times be affected by backwater from North Fork.

Discharge measurements are made from the downstream side of the footbridge. The initial point for soundings is the center of a telegraph pole on the right bank, marked with a 20-penny nail and zero.

A plain-staff gage is attached to the right pile bent of the bridge. During 1905 the gage was read once each day by A. C. McLaughlin. Bench marks were established as follows: (1) A standard United States Geological Survey tablet marked "2537" set in the vertical wall of a brick house on the corner one square north of the Bank of Tekoa; elevation, 62.11 feet. (2) Top of the head of a 60-penny spike driven into the telegraph pole at the initial point for soundings; elevation, 11.41 feet. Elevations refer to the datum of the gage.

A description of this station, with gage heights, discharge data, and rating table, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 51–54.

*Daily gage height, in feet, of Hangman Creek at Tekoa, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.1 | 0.9 | 1.9 | 3.0 | 1.5 | 1.7 | 1.0 | 0.45 | 0.2 |
| 2 | .1 | .9 | 1.8 | 3.0 | 1.4 | 1.65 | 1.0 | .4 | .2 |
| 3 | .15 | .5 | 1.7 | 2.6 | 1.4 | 1.85 | .9 | .4 | .3 |
| 4 | .1 | .5 | 1.7 | 2.5 | 1.3 | 2.0 | .9 | .4 | .3 |
| 5 | .1 | .5 | 1.7 | 2.3 | 1.3 | 2.4 | .8 | .4 | .3 |
| 6 | .9 | .4 | 1.7 | 2.2 | 1.2 | 2.8 | .8 | .4 | .3 |
| 7 | .9 | .4 | 1.6 | 2.2 | 1.0 | 3.6 | .85 | .45 | .3 |
| 8 | .8 | .4 | 1.5 | 2.0 | 1.0 | 2.9 | .7 | a.3 | .3 |
| 9 | .75 | .3 | 1.5 | 2.0 | 1.5 | 2.3 | .7 | .3 | .3 |
| 10 | .7 | .3 | 1.5 | 2.0 | 1.8 | 2.0 | .7 | .3 | .3 |
| 11 | .65 | .1 | 1.5 | 1.9 | 1.6 | 2.0 | .7 | .3 | .3 |
| 12 | .65 | .2 | 1.5 | 1.8 | 1.5 | 1.9 | .6 | .3 | .3 |
| 13 | .65 | .3 | 1.47 | 1.7 | 2.6 | 1.8 | .6 | .3 | .3 |
| 14 | .65 | .3 | 1.47 | 1.7 | 2.5 | 1.5 | .6 | .3 | .3 |
| 15 | .65 | .4 | 1.47 | 1.5 | 2.3 | 1.55 | .6 | .3 | .3 |
| 16 | .65 | .5 | 1.47 | 1.7 | 2.0 | 1.3 | .65 | .3 | .3 |
| 17 | .65 | .6 | 1.47 | 1.9 | 1.9 | 1.3 | .65 | .3 | .4 |
| 18 | .6 | .6 | 1.3 | 2.0 | 1.8 | 1.2 | .65 | .3 | .4 |
| 19 | .6 | .7 | 2.0 | 2.0 | 1.6 | 1.15 | .65 | .3 | .4 |
| 20 | .6 | 1.2 | 2.0 | 2.8 | 1.6 | 1.1 | .65 | .3 | .4 |
| 21 | .6 | 1.6 | 2.1 | 3.6 | 1.6 | 1.0 | .6 | .3 | .4 |
| 22 | .1 | 1.4 | 2.1 | 3.3 | 1.6 | 1.0 | .6 | .3 | .4 |
| 23 | .18 | 1.5 | 2.2 | 2.7 | 1.7 | 1.0 | .55 | .3 | .4 |
| 24 | .26 | 1.7 | 2.3 | 2.3 | 1.8 | 1.2 | .55 | .3 | .4 |
| 25 | .28 | 1.9 | 3.0 | 2.0 | 2.6 | 1.2 | .55 | .3 | .4 |
| 26 | .25 | .2 | 3.6 | 1.9 | 2.8 | 1.0 | .55 | .3 | .5 |
| 27 | .25 | .2 | 3.8 | 1.77 | 2.5 | 1.15 | .5 | .2 | .5 |
| 28 | .19 | 1.9 | 3.35 | 1.7 | 2.2 | 1.3 | .5 | .2 | .6 |
| 29 | 1.8 | ..... | 3.3 | 1.5 | 2.1 | 1.2 | .5 | .2 | .6 |
| 30 | 1.8 | ..... | 3.3 | 1.5 | 1.97 | 1.0 | .45 | .2 | .6 |
| 31 | 1.8 | ..... | 3.3 | ..... | 1.8 | ..... | .45 | .2 | ..... |

aWater standing in pools.

NOTE.—Ice conditions January 22 to February 15 approximately. Gage read to water surface.

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## HANGMAN CREEK AT POOLE'S RANCH, NEAR TEKOA, WASH.

This station was established September 28, 1904, by T. A. Noble, and discontinued September 30, 1905. It is located 4 miles northwest of Tekoa, Wash., one-fourth mile south of the highway bridge across Hangman Creek, and 300 feet south of J. M. Poole's farm crossing.

The channel is straight for about 80 feet above and 25 feet below the station, and the current is sluggish. Both banks are about 6 to 8 feet high, lined with brush, and subject to overflow during high water. The bed of the stream is composed of rock and cemented gravel, is free from vegetation, and is permanent. There is but one channel at low and two at high water.

Discharge measurements are made by means of a weir 14 feet long. The top of the weir is at the same height as the top of a nail driven into the plank which forms part of the deadman for the bench mark, 7 feet upstream from the weir.

During 1905 a 6-inch hook gage was used once each day by John M. Poole. The bench mark is the top of a 60-penny nail driven into the right-of-way post of the Oregon Railroad and Navigation Company, 40 feet east of the weir; elevation, 8.627 feet above the top of the weir or iron lip.

A description of this station, with gage heights, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 54–55.

*Daily discharge, in second-feet, of Hangman Creek at Poole's ranch, near Tekoa, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | Day. | Jan. | Feb. | Mar. | Apr. | Day. | Jan. | Feb. | Mar. | Apr. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | [a] 16 | 5 | ..... | ..... | 10 | 7 | 9 | ..... | 58 | 18 | ..... | 6 | 30 | ..... |
| 2 | [b] 22 | ..... | ..... | ..... | 11 | 5 | 5 | ..... | 52 | 19 | ..... | 8 | (e) | ..... |
| 3 | 24 | 17 | ..... | ..... | 12 | 5 | 5 | ..... | 45 | 20 | ..... | (f) | ..... | ..... |
| 4 | 17 | 12 | ..... | ..... | 13 | (c) | 5 | ..... | 41 | 22 | ..... | ..... | 73 | ..... |
| 5 | 13 | 10 | ..... | 73 | 14 | ..... | 4 | ..... | 35 | 23 | ..... | ..... | 73 | ..... |
| 6 | 10 | 10 | ..... | 69 | 15 | ..... | 5 | ..... | 31 | 24 | ..... | ..... | (f) | ..... |
| 7 | 10 | 10 | ..... | 65 | 16 | ..... | 4 | [d] 32 | ..... | 30 | 16 | ..... | ..... | ..... |
| 8 | 9 | 8 | ..... | 64 | 17 | ..... | 4 | 27 | ..... | 31 | 6 | ..... | ..... | ..... |
| 9 | 8 | 6 | ..... | 61 | | | | | | | | | | |

[a] Length of weir 7 feet, January 1.
[b] Length of weir 10 feet, January 2–12, January 30 to February 19.
[c] River frozen up January 13–14.
[d] Length of weir 13 feet, March 16–18.
[e] Length of weir 12 feet 8 inches, March 19–23, April 5–15.
[f] River overflowed, February 20–25, March 24–25.

## NORTH FORK OF HANGMAN CREEK AT TEKOA, WASH.

This station was established April 2, 1904, by W. W. Schlecht, and discontinued September 30, 1905. It is located at the highway bridge in Tekoa, Wash., on the road leading north.

The channel is straight for about 60 feet above and below the station and the current is swift. There is a series of rapids between the gaging station and the mouth of the creek, having a total fall of about 4 to 5 feet. The right bank is of earth, fringed with brush, having a number of houses built close to the river, and does not overflow. The left bank is low, and is liable to overflow above and below the station 50 to 100 feet back to the railroad embankment. The bed of the stream is composed of gravel and a few bowlders, and is permanent. At the gaging section there is but one channel at all stages.

Discharge measurements are made from the downstream side of the highway bridge. The initial point for soundings is the center of telegraph pole on the right bank. It is indicated by a 20-penny nail and marked zero.

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A plain-staff gage is fastened to the concrete abutment of the railway bridge on the northern arm of the "Y" of the Oregon Railroad and Navigation Company's tracks, 25 feet upstream from the bridge, from which discharge measurements are made. During 1905 the gage was read once each day by C. J. McLaughlin. Bench marks were established as follows: (1) A United States Geological Survey standard aluminum tablet set in the vertical wall of a brick house on the corner one square north of the bank in Tekoa, marked "2537;" elevation, 58.29 feet. (2) A point on the concrete abutment of the railroad bridge near the gage; elevation, 8.39 feet. Elevations refer to the datum of the gage.

April 9, 1905, a discharge measurement made at this station by Schlecht and Hohlen gave the following results: Width, 44 feet; area of section, 108 square feet; mean velocity, 1.09 feet per second; gage height, 1.88 feet; discharge, 117 second-feet.

A description of this station, with gage height, discharge data, and rating table, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 55–57.

*Daily gage height, in feet, of North Fork of Hangman Creek at Tekoa, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.99 | 0.8 | 2.0 | 2.5 | 1.8 | 1.8 | 1.5 | 0.35 | 0.5 |
| 2 | .99 | .8 | 1.9 | 2.5 | 1.7 | 1.8 | 1.5 | .4 | .5 |
| 3 | 1.0 | .4 | 1.9 | 2.4 | 1.7 | 2.4 | 1.4 | .4 | .5 |
| 4 | .97 | .4 | 1.9 | 2.4 | 1.7 | 2.4 | 1.4 | .4 | .5 |
| 5 | .8 | .4 | 1.7 | 2.4 | 1.7 | 2.3 | 1.4 | .4 | .5 |
| 6 | .75 | .3 | 1.4 | 2.4 | 1.7 | 1.4 | 1.4 | .4 | .5 |
| 7 | .65 | .3 | 1.3 | 2.4 | 1.7 | 2.3 | 1.3 | .4 | .5 |
| 8 | .6 | .3 | 1.2 | 2.3 | 1.65 | 2.3 | 1.3 | .4 | .5 |
| 9 | .55 | .2 | 1.0 | 2.3 | 1.7 | 2.1 | 1.3 | .35 | .5 |
| 10 | .55 | .2 | .9 | 2.3 | 1.6 | 2.0 | 1.2 | .35 | .5 |
| 11 | .55 | .2 | .9 | 2.1 | 1.5 | 1.9 | .9 | .35 | .5 |
| 12 | .55 | .3 | .9 | 2.0 | 1.5 | 1.8 | .8 | .4 | .5 |
| 13 | .5 | .3 | .8 | 1.9 | 1.6 | 1.7 | .8 | .4 | .5 |
| 14 | .5 | .4 | .8 | 1.9 | 2.5 | 1.7 | .35 | .5 | .5 |
| 15 | .5 | .4 | .8 | 1.8 | 2.5 | 1.5 | .35 | .5 | .5 |
| 16 | .5 | .4 | .8 | 1.8 | 2.4 | 1.5 | .5 | .5 | .5 |
| 17 | .5 | .5 | .8 | 1.8 | 2.3 | 1.5 | .5 | .5 | .5 |
| 18 | .5 | .6 | .8 | 1.9 | 1.8 | 1.5 | .4 | .5 | .5 |
| 19 | .49 | .7 | .8 | 2.0 | 1.8 | 1.5 | .4 | .5 | .5 |
| 20 | .49 | 1.0 | .8 | 2.2 | 1.8 | 1.3 | .4 | .5 | .5 |
| 21 | .48 | 1.5 | 1.0 | 2.3 | 1.8 | 1.2 | .45 | .5 | .5 |
| 22 | .48 | 1.5 | 1.3 | 2.3 | 1.8 | 1.2 | .45 | .5 | .5 |
| 23 | .1 | 1.4 | 1.3 | 2.2 | 1.9 | 1.3 | .45 | .5 | .5 |
| 24 | .15 | 1.4 | 1.4 | 2.1 | 1.9 | 1.6 | .45 | .5 | .5 |
| 25 | .15 | 1.5 | 1.5 | 2.0 | 1.9 | 1.5 | .45 | .5 | .5 |
| 26 | .1 | 1.7 | 2.9 | 2.0 | 1.9 | 1.7 | .4 | .5 | .5 |
| 27 | .1 | 1.9 | 2.7 | 1.9 | 1.8 | 1.7 | .3 | .5 | .5 |
| 28 | .1 | 2.2 | 2.5 | 1.8 | 1.8 | 1.65 | .3 | .5 | .6 |
| 29 | 1.1 | ..... | 2.6 | 1.8 | 2.3 | 1.55 | .3 | .5 | .6 |
| 30 | 1.1 | ..... | 2.6 | 1.8 | 2.0 | 1.5 | .35 | .5 | .6 |
| 31 | 1.1 | ..... | 2.6 | ..... | 1.9 | ..... | .35 | ..... | ..... |

NOTE.—Ice conditions during part of January and February. Gage read to water surface.

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### LITTLE SPOKANE RIVER NEAR SPOKANE, WASH.

This station was established August 3, 1903, by George H. Bliss, and was discontinued March 31, 1905. It is located about 2 miles above the mouth of the river at the second bridge above the mouth. It is 9 miles northwest of Spokane, Wash., and 1½ miles northeast of what is known as the "9-mile bridge" over Spokane River.

The channel is straight for 100 feet above and 150 feet below the station. The current is swift. Both banks are high, covered with underbrush, and liable to overflow only at very high stages. The bed of the stream is composed of clean gravel. The channel is broken by four bridge piers and has a width at ordinary stages of about 125 feet.

Discharge measurements are made from the upstream side of the bridge to which the gage is attached. The initial point for soundings is the vertical end post on the upstream side of the bridge at the south approach.

A wire gage is located on the upstream side of the bridge; length of wire, 13.25 feet. This distance has been laid off on the upper surface of the bottom rail near the gage and is marked by copper tacks inclosed in circles of black paint. These marks are used in checking the length of the gage wire. During 1905 the gage was read once each day by Mary A. Keenan. The bench mark is a wire nail driven into the root of a pine tree 2 feet in diameter, on the north side of the tree, toward the bridge, 60 feet distant from the south end of the bridge; elevation, 21.00 feet above the datum of the gage.

A description of this station, with gage height and discharge data, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 57–59.

*Daily gage height, in feet, of Little Spokane River near Spokane, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Day. | Jan. | Feb. | Mar. | Day. | Jan. | Feb. | Mar. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.7 | 6.5 | 7.0 | 12 | 6.35 | 6.07 | 7.2 | 23 | 6.75 | 6.5 | 7.88 |
| 2 | 6.7 | 6.54 | 7.1 | 13 | 6.4 | 6.33 | 7.18 | 24 | 6.9 | 6.89 | 7.74 |
| 3 | 6.65 | 6.62 | 7.2 | 14 | 6.59 | 6.33 | 7.04 | 25 | 6.8 | 7.15 | 7.75 |
| 4 | 6.55 | 6.5 | 7.3 | 15 | 6.75 | 6.4 | 7.2 | 26 | 7.0 | 7.09 | 7.75 |
| 5 | 6.6 | 6.47 | 7.35 | 16 | 6.59 | 6.3 | 7.0 | 27 | 6.9 | 7.1 | 7.7 |
| 6 | 6.37 | 6.4 | 7.2 | 17 | 6.38 | 6.29 | 6.9 | 28 | 7.25 | 7.0 | 7.71 |
| 7 | 6.45 | 6.43 | 7.1 | 18 | 6.4 | 6.1 | 6.85 | 29 | 7.4 | ..... | 7.65 |
| 8 | 6.3 | 6.5 | 6.95 | 19 | 6.36 | 6.35 | 6.9 | 30 | 7.0 | ..... | 7.8 |
| 9 | 6.6 | 6.4 | 7.05 | 20 | 6.4 | 6.39 | 7.32 | 31 | 6.7 | ..... | 7.6 |
| 10 | 6.31 | 6.23 | 7.15 | 21 | 6.45 | 6.28 | 7.4 | | | | |
| 11 | 6.45 | 6.1 | 7.15 | 22 | 6.6 | 6.1 | 7.97 | | | | |

NOTE.—No ice record.

## OKANOGAN RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Okanogan River rises in Okanogan Lake, British Columbia, and flows southward, entering Columbia River near Brewster, Wash. Throughout its course in Canada the river flows through a chain-like series of lakes.

### SINLAHEKIN CREEK NEAR LOOMIS, WASH.

This station was established June 13, 1903, by Charles E. Hewitt, and was discontinued March 30, 1905. It is located on the main road between Loomis and Conconully, Wash., 3 miles from Loomis and 19 miles from Conconully.

The channel is straight for 20 feet above and for 50 feet below the station. Beyond these points are large bends in the stream. The right bank is low for about 15 feet back from the water's edge. Beyond this point it rises more abruptly and is not subject to overflow.

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The water's edge is covered with shrubbery. The left bank is low grass land, subject to overflow. The bed of the stream is a gravelly clay or loam and is fairly stable.

Discharge measurements are made from a plank footbridge. The initial point for soundings is an iron bar driven flush with the ground at the northeast corner of the main part of Mr. R. A. Garrett's house.

The gage is a vertical staff driven into the ground and braced to the gatepost at the northeast corner of Mr. Garrett's yard. During 1905 the gage was read once each day by Mrs. Mary Garrett. The bench mark is the top of the iron bar used as the initial point for sounding: elevation, 11.40 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 394; 135, p 59.
Discharge: 100, p. 395
Discharge, monthly: 135, p 61.
Gage heights: 100, p 395; 135, p 60.
Rating table: 135, p 60.

*Daily gage height, in feet, of Sinlahekin Creek near Loomis, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Day. | Jan. | Feb. | Mar. | Day. | Jan. | Feb. | Mar. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.7 | 2.7 | 2.6 | 12 | 2.7 | 2.8 | 2.65 | 22 | 2.7 | 4.3 | 3.0 |
| 2 | 2.7 | 2.65 | 2.6 | 13 | 2.7 | 3.0 | 2.6 | 23 | 2.7 | 4.0 | 2.9 |
| 3 | 2.7 | 2.65 | 2.6 | 14 | 2.75 | 3.0 | 2.6 | 24 | 2.7 | 3.5 | 3.0 |
| 4 | 2.7 | 2.7 | 2.6 | 15 | 2.85 | 3.0 | 2.6 | 25 | 2.7 | 2.9 | 3.0 |
| 5 | 2.7 | 2.7 | 2.6 | 16 | 3.2 | 3.0 | 2.6 | 26 | 2.7 | 2.6 | 3.0 |
| 6 | 2.7 | 2.7 | 2.6 | 17 | 3.5 | 3.0 | 2.65 | 27 | 2.7 | 2.6 | 2.9 |
| 7 | 2.7 | 2.7 | 2.6 | 18 | 3.3 | 3.1 | 2.65 | 28 | 2.7 | 2.6 | 2.9 |
| 8 | 2.7 | 2.7 | 2.6 | 19 | 3.0 | 3.2 | 2.7 | 29 | 2.7 | ..... | 2.8 |
| 9 | 2.7 | 2.7 | 2.6 | 20 | 3.0 | 3.7 | 2.8 | 30 | 2.7 | ..... | 2.8 |
| 10 | 2.7 | 2.7 | 2.6 | 21 | 2.8 | 5.15 | 3.25 | 31 | 2.7 | ..... | 2.8 |
| 11 | 2.7 | 2.75 | 2.7 | | | | | | | | |

NOTE.—No ice record.

## SALMON CREEK NEAR MALOTT, WASH.

This station was established April 11, 1903, by T. A. Noble. It is located opposite R. D. Jones's house, which is on the county road halfway between Malott and Conconully, Okanogan County. It is reached by way of the Great Northern Railway to Wenache, thence by way of the Columbia River steamers to Brewster, and by the Conconully stage from Brewster to Jones's ranch.

The channel is straight for 100 feet above and 200 feet below the station. There are rapids at the bend in the river 100 feet above the station and at another bend 300 feet below the station. The current is swift. The right bank is low and will overflow for about 100 feet, at which point it becomes steep. The left bank is low and may overflow for 200 feet at extreme flood stages. Both banks are without trees or brush with the exception of a fringe of alder at the water's edge. The bed is rocky at the center and sandy along the banks. It is without vegetation except near the banks.

Discharge measurements are made from the footbridge. The initial point for soundings is a nail driven in a birch hub, 4 feet east of the bridge and 14 feet north of the gage. It is on the left bank, 7 feet from the water's edge at ordinary stages.

The gage is a vertical staff fastened to a small alder tree on the left bank of the river opposite the house of the observer, R. D. Jones, who during 1905 read the gage once each day. The bench mark is the initial point for soundings; elevation, 4.58 feet above the datum of the gage.

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Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey·

Description: 100, pp 389–390; 135, p 63
Discharge: 100, p 390; 135, p 64.
Discharge, monthly: 100, p 392; 135, p 65.
Gage heights: 100, p 391; 135, p 64.
Rating table: 100, p 391; 135, p 65.

*Discharge measurements of Salmon Creek near Malott, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 4 | O. Laurgaard | 28 | 82 | 4.43 | 2.67 | 362 |
| June 16 | do. | 27 | 56 | 2.72 | 1.80 | 154 |
| July 27 | do. | 25 | 34 | 1.22 | 1.10 | 41 |
| November 1 | do. | 24 | 32 | .77 | .90 | 24 |

*Daily gage height, in feet, of Salmon Creek near Malott, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.69 | 0.73 | 0.94 | 0.98 | 1.67 | 2.18 | 1.81 | 0.99 | 0.93 | 0.75 | 0.88 | 0.61 |
| 2 | .77 | .74 | .96 | .96 | 1.62 | 2.25 | 1.94 | .96 | .9 | .73 | .82 | .67 |
| 3 | .71 | .74 | .99 | .94 | 1.66 | 2.3 | 1.91 | .94 | .96 | .75 | .79 | .69 |
| 4 | .72 | .75 | .99 | .9 | 1.6 | 2.83 | 1.88 | .92 | .83 | .75 | .81 | .7 |
| 5 | .75 | .77 | 1.0 | .97 | 1.67 | 2.46 | 1.75 | .92 | .82 | .88 | .81 | .71 |
| 6 | .77 | .75 | .99 | 1.08 | 1.71 | 2.43 | 1.69 | .88 | .75 | .92 | .79 | .75 |
| 7 | .75 | .73 | .97 | 1.10 | 1.75 | 2.33 | 1.62 | .83 | .73 | .98 | .78 | .75 |
| 8 | .73 | .71 | 1.0 | 1.12 | 1.91 | 2.24 | 1.58 | .81 | .73 | 1.0 | .77 | .75 |
| 9 | .71 | .67 | 1.01 | 1.15 | 1.92 | 2.34 | 1.54 | .79 | .74 | .88 | .76 | .74 |
| 10 | .67 | .65 | 1.02 | 1.17 | 1.96 | 2.31 | 1.5 | .77 | .74 | .83 | .75 | .72 |
| 11 | .68 | .66 | 1.04 | 1.19 | 1.88 | 2.27 | 1.48 | 1.12 | .73 | .83 | .77 | .73 |
| 12 | .71 | .67 | 1.05 | 1.2 | 1.75 | 2.24 | 1.46 | 1.11 | .73 | .81 | .79 | .74 |
| 13 | .72 | .69 | 1.07 | 1.21 | 1.75 | 2.06 | 1.45 | 1.12 | .74 | .77 | .77 | .75 |
| 14 | .74 | .68 | 1.08 | 1.19 | 1.71 | 1.97 | 1.44 | 1.1 | .79 | .75 | .76 | .75 |
| 15 | .75 | .67 | 1.1 | 1.18 | 1.69 | 1.91 | 1.44 | 1.1 | .81 | .83 | .75 | .74 |
| 16 | .76 | .66 | 1.1 | 1.25 | 1.68 | 1.83 | 1.43 | 1.08 | .79 | .79 | .76 | .75 |
| 17 | .77 | .71 | 1.12 | 1.38 | 1.75 | 1.79 | 1.38 | 1.08 | .81 | .81 | .77 | .76 |
| 18 | .77 | .67 | 1.12 | 1.35 | 1.69 | 1.76 | 1.33 | 1.08 | .79 | .79 | .79 | .77 |
| 19 | .78 | .72 | 1.14 | 1.38 | 1.67 | 1.77 | 1.29 | 1.06 | .71 | .83 | .83 | .75 |
| 20 | .78 | .73 | 1.12 | 1.6 | 1.62 | 1.79 | 1.27 | 1.04 | .69 | .85 | .75 | .75 |
| 21 | .79 | .77 | 1.1 | 1.64 | 1.6 | 1.83 | 1.25 | 1.02 | .69 | .81 | .62 | .7 |
| 22 | .8 | .78 | 1.09 | 1.67 | 1.61 | 1.85 | 1.17 | 1.0 | .09 | .79 | .61 | .54 |
| 23 | .82 | .82 | 1.1 | 1.71 | 1.71 | 1.71 | 1.12 | 1.0 | .67 | .79 | .62 | .58 |
| 24 | .83 | .83 | 1.1 | 1.88 | 1.73 | 1.88 | 1.08 | .99 | .64 | .83 | .6 | .62 |
| 25 | .83 | .83 | 1.12 | 2.0 | 1.85 | 1.92 | 1.06 | .99 | .69 | .85 | .58 | .67 |
| 26 | .84 | .85 | 1.1 | 2.04 | 1.83 | 2.08 | 1.0 | .96 | .83 | .9 | .57 | .73 |
| 27 | .81 | .84 | 1.09 | 1.93 | 1.83 | 2.12 | 1.04 | .96 | .81 | .83 | .5 | .73 |
| 28 | .79 | .85 | .92 | 1.88 | 1.88 | 2.09 | 1.06 | .92 | .88 | .81 | .5 | .74 |
| 29 | .79 | ..... | 1.07 | 1.81 | 1.88 | 1.94 | 1.06 | .94 | .83 | .75 | .54 | .72 |
| 30 | .77 | ..... | 1.05 | 1.74 | 1.91 | 1.88 | 1.04 | .92 | .79 | .64 | .55 | .71 |
| 31 | .73 | ..... | 1.02 | ..... | 2.0 | ..... | 1.0 | .92 | ..... | .71 | ..... | .7 |

NOTE.—No ice record.

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*Station rating table for Salmon Creek near Malott, Wash., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.50 | 7 | 1.20 | 53 | 1.80 | 154 | 2.40 | 289 |
| 0.60 | 9 | 1.30 | 66 | 1.90 | 174 | 2.50 | 316 |
| 0.70 | 12 | 1.40 | 81 | 2.00 | 194 | 2.60 | 343 |
| 0.80 | 17 | 1.50 | 98 | 2.10 | 215 | 2.70 | 371 |
| 0.90 | 24 | 1.60 | 116 | 2.20 | 238 | 2.80 | 400 |
| 1.00 | 31 | 1.70 | 134 | 2.30 | 263 | 2.90 | 432 |
| 1.10 | 41 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on four discharge measurements made during 1905. It is well defined between gage heights 0.8 foot and 2.6 feet.

*Estimated monthly discharge of Salmon Creek near Malott, Wash., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 20 | 11 | 15.0 | 922 |
| February | 20 | 10 | 14.1 | 783 |
| March | 46 | 25 | 36.3 | 2,232 |
| April | 202 | 24 | 87.5 | 5,207 |
| May | 194 | 116 | 146. | 8,977 |
| June | 410 | 134 | 215. | 12,790 |
| July | 182 | 31 | 85.4 | 5,251 |
| August | 43 | 16 | 30.3 | 1,863 |
| September | 28 | 10 | 16.2 | 964 |
| October | 31 | 10 | 18.3 | 1,125 |
| November | 23 | 7 | 13.7 | 815 |
| December | 16 | 8 | 12.8 | 787 |
| The year | 410 | 7 | 57.6 | 41,720 |

## METHOW RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Methow River has its source in the Cascade Mountains near the boundary line between the United States and British Columbia, and flows in a southeast direction into Columbia River. The stream is a very rapid one and is at present used to a considerable extent for irrigation purposes.

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## METHOW RIVER NEAR PATEROS, WASH.

This station was originally established May 3, 1903, by T. A. Noble, and was located on a highway bridge about 1,000 feet above the mouth of the river. The first two measurements were taken from this bridge. During the summer of 1903 this bridge was washed away, and a temporary bridge 400 feet farther downstream was used in making the measurement of March 20, 1904.

During the spring of 1904 this bridge also was abandoned because of its temporary nature and the poor section at this point, and a cable station was established about a mile above the mouth of the river.

Both banks at the station are high and not liable to overflow. The bed of the stream is covered with small bowlders and gravel and is liable to changes. The section is good, except at the highest stage of the river. At such times the current at the station becomes too swift to measure, and it is necessary to use a boat farther down the stream, where the backwater from Columbia River retards the current.

The initial point for soundings is a cross marked "I. P." on rock about 10 feet back of the cable support on the left bank.

The gage is located about 500 feet below the cable, above any effect of backwater from Columbia River. It is fastened between two pine trees on the left bank. The lower section is inclined and reads from 0 to 10 feet. The upper section is vertical and reads from 10 to 19 feet. All gage heights given below and all discharge measurements are referred to this gage. A secondary gage is in place at the cable to be used by the hydrographer at the time of measurement, to assist in computing areas. During 1905 the gage was read once each day by K. K. Parker. Bench marks were established as follows: (1) A United States Gelogical Survey standard iron post in front of Ives Hotel, at Pateros, Wash.; elevation, 26.05 feet above zero of the gage and 780 feet above sea level. (2) The top of a large white stone, marked "B. M." which is 30 feet northeast of the gage board on the left bank; elevation, of the highest point, 15.20 feet above gage datum.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 387–388; 135, pp 65–66.
Discharge: 100, p 388; 135, p 66.
Discharge, monthly: 135, p 68.
Gage heights: 100, p 389; 135, p 67.
Rating table: 135, p 67.

*Discharge measurements of Methow River near Pateros, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| May 6 | O. Laurgaard | 178 | 730 | 4.27 | 6.50 | 3,116 |
| November 4 | do | 164 | 408 | 1.68 | 4.60 | 685 |
| November 28 | W. C. Sawyer | 155 | 380 | 1.62 | 4.30 | 618 |

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*Daily gage height, in feet, of Methow River near Pateros, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.15 | 4.2 | 4.1 | 5.4 | 6.7 | 9.1 | 7.6 | 4.4 | 4.35 | 4.4 | 4.65 | 4.2 |
| 2 | 4.15 | 4.2 | 4.1 | 5.3 | 6.7 | 9.8 | 7.55 | 5.35 | 4.3 | 4.45 | 4.65 | 4.2 |
| 3 | 4.15 | 4.15 | 4.15 | 5.3 | 6.7 | 10.0 | 7.55 | 5.35 | 4.3 | 4.45 | 4.65 | 4.25 |
| 4 | 4.15 | 4.15 | 4.15 | 5.3 | 6.5 | 10.4 | 7.5 | 5.3 | 4.25 | 5.0 | 4.6 | 4.25 |
| 5 | 4.15 | 4.15 | 4.25 | 5.3 | 6.5 | 10.0 | 7.4 | 5.3 | 4.25 | 4.45 | 4.55 | 4.25 |
| 6 | 4.15 | 4.1 | 4.3 | 5.3 | 6.5 | 10.0 | 7.1 | 5.2 | 4.2 | 4.45 | 4.55 | 4.3 |
| 7 | 4.15 | 4.05 | 4.3 | 5.4 | 6.5 | 10.0 | 6.95 | 5.15 | 4.2 | 4.45 | 4.55 | 4.25 |
| 8 | 4.1 | 4.05 | 4.3 | 5.4 | 6.85 | 10.0 | 6.9 | 5.1 | 4.2 | 4.6 | 4.5 | 4.2 |
| 9 | 4.05 | 4.1 | 4.4 | 5.45 | 7.9 | 10.3 | 6.85 | 5.0 | 4.25 | 4.75 | 4.5 | 4.2 |
| 10 | 4.0 | 4.15 | 5.0 | 5.45 | 7.8 | 10.2 | 6.75 | 4.95 | 4.25 | 4.9 | 4.5 | 4.2 |
| 11 | 4.0 | 3.8 | 5.4 | 5.45 | 7.5 | 10.0 | 6.6 | 4.9 | 4.2 | 4.9 | 4.5 | 4.2 |
| 12 | 4.0 | 4.2 | 5.4 | 5.55 | 7.45 | 9.8 | 6.4 | 4.85 | 4.2 | 4.85 | 4.5 | 4.15 |
| 13 | 4.0 | 4.15 | 5.4 | 5.6 | 7.2 | 9.7 | 6.3 | 4.85 | 4.2 | 4.8 | 4.5 | 4.15 |
| 14 | 4.0 | 4.2 | 5.35 | 5.65 | 7.15 | 8.7 | 6.25 | 4.8 | 4.2 | 4.75 | 4.45 | 4.15 |
| 15 | 4.0 | 4.2 | 5.3 | 5.65 | 7.1 | 8.4 | 6.2 | 4.75 | 4.2 | 4.7 | 4.4 | 4.15 |
| 16 | 4.0 | 4.2 | 5.3 | 5.7 | 7.0 | 8.3 | 6.0 | 4.75 | 4.2 | 4.7 | 4.5 | 4.15 |
| 17 | 4.0 | 4.2 | 5.4 | 5.75 | 7.0 | 8.1 | 5.95 | 4.75 | 4.2 | 4.7 | 4.5 | 4.1 |
| 18 | 4.1 | 4.2 | 5.6 | 5.75 | 7.0 | 7.9 | 5.9 | 4.7 | 4.2 | 4.7 | 4.5 | 4.1 |
| 19 | 4.2 | 4.2 | 5.7 | 5.8 | 7.0 | 8.0 | 5.85 | 4.65 | 4.2 | 4.7 | 4.5 | 4.1 |
| 20 | 4.2 | 4.25 | 5.75 | 5.9 | 7.0 | 8.05 | 5.8 | 4.6 | 4.2 | 4.65 | 4.45 | 4.1 |
| 21 | 4.1 | 4.2 | 5.8 | 6.05 | 7.0 | 8.05 | 5.8 | 4.5 | 4.2 | 4.6 | 4.4 | 4.1 |
| 22 | 4.1 | 4.2 | 5.7 | 6.3 | 6.9 | 8.05 | 5.8 | 4.5 | 4.2 | 4.5 | 4.4 | 4.1 |
| 23 | 4.1 | 4.2 | 5.65 | 6.8 | 6.9 | 8.05 | 5.8 | 4.45 | 4.2 | 4.5 | 4.45 | 4.1 |
| 24 | 4.1 | 4.15 | 5.6 | 7.15 | 6.8 | 8.35 | 5.75 | 4.45 | 4.2 | 4.5 | 4.45 | 4.1 |
| 25 | 4.1 | 4.1 | 5.6 | 7.9 | 6.75 | 8.25 | 5.6 | 4.45 | 4.25 | 4.5 | 4.45 | 4.1 |
| 26 | 4.1 | 4.05 | 5.55 | 8.0 | 6.7 | 8.1 | 5.65 | 4.45 | 4.3 | 4.5 | 4.45 | 4.1 |
| 27 | 4.05 | 4.1 | 5.55 | 7.75 | 7.0 | 8.05 | 5.7 | 4.4 | 4.4 | 4.6 | 4.4 | 4.1 |
| 28 | 4.05 | 4.1 | 5.5 | 7.6 | 7.2 | 7.9 | 5.6 | 4.4 | 4.4 | 4.75 | 4.3 | 4.1 |
| 29 | 4.0 | ..... | 5.4 | 7.1 | 7.7 | 7.7 | 5.6 | 4.4 | 4.4 | 4.75 | 4.25 | 4.1 |
| 30 | 3.8 | ..... | 5.4 | 7.0 | 8.0 | 7.65 | 5.55 | 4.4 | 4.4 | 4.7 | 4.2 | 4.0 |
| 31 | 4.2 | ..... | 5.4 | ..... | 8.7 | ..... | 5.5 | 4.35 | ..... | 4.7 | ..... | 4.0 |

NOTE.—Some ice along shores during February.

*Station rating table for Methow River near Pateros, Wash., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.80 | 400 | 5.10 | 1,166 | 6.40 | 2,884 | 8.20 | 6,264 |
| 3.90 | 420 | 5.20 | 1,266 | 6.50 | 3,050 | 8.40 | 6,674 |
| 4.00 | 450 | 5.30 | 1,372 | 6.60 | 3,216 | 8.60 | 7,088 |
| 4.10 | 486 | 5.40 | 1,484 | 6.70 | 3,386 | 8.80 | 7,506 |
| 4.20 | 528 | 5.50 | 1,602 | 6.80 | 3,560 | 9.00 | 7,930 |
| 4.30 | 576 | 5.60 | 1,724 | 6.90 | 3,738 | 9.20 | 8,356 |
| 4.40 | 630 | 5.70 | 1,854 | 7.00 | 3,920 | 9.40 | 8,785 |
| 4.50 | 690 | 5.80 | 1,988 | 7.20 | 4,294 | 9.60 | 9,215 |
| 4.60 | 756 | 5.90 | 2,128 | 7.40 | 4,676 | 9.80 | 9,646 |
| 4.70 | 826 | 6.00 | 2,272 | 7.60 | 5,066 | 10.00 | 10,080 |
| 4.80 | 902 | 6.10 | 2,420 | 7.80 | 5,460 | 10.20 | 10,518 |
| 4.90 | 984 | 6.20 | 2,572 | 8.00 | 5,860 | 10.40 | 10,960 |
| 5.00 | 1,072 | 6.30 | 2,726 | | | | |

The above table is applicable only for open-channel conditions. It is based on 10 discharge measurements made during 1903–5. It is well defined.

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*Estimated monthly discharge of Methow River near Pateros, Wash., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 528 | 400 | 480 | 29,510 |
| February | 552 | 400 | 506 | 28,100 |
| March | 1,988 | 486 | 1,291 | 79,380 |
| April | 5,860 | 1,372 | 2,517 | 149,800 |
| May | 7,296 | 3,050 | 4,110 | 252,700 |
| June | 10,960 | 5,164 | 7,749 | 461,100 |
| July | 5,066 | 1,602 | 2,839 | 174,600 |
| August | 1,428 | 603 | 899 | 55,280 |
| September | 630 | 528 | 553 | 32,910 |
| October | 1,072 | 630 | 792 | 48,700 |
| November | 791 | 528 | 678 | 40,340 |
| December | 576 | 450 | 507 | 31,170 |
| The year | 10,960 | 400 | 1,910 | 1,384,000 |

NOTE.—Discharge applied as for open channel during February.

## CHELAN RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

The Chelan is a short river, being only about 4 miles in length. It connects Lake Chelan with Columbia River, entering the latter at Chelan Falls. It is valuable principally for the water power that can be developed on it.

### LAKE CHELAN AT CHELAN, WASH.

A gage is attached to one of the bents of the upper bridge at Chelan, Wash. It is above the controlling dam and gives fluctuations of the lake surface only.

*Daily gage height, in feet, of Lake Chelan at Chelan, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | Day. | Jan. | Feb. | Mar. | Apr. | May. | June. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.4 | 2.25 | 1.8 | 2.18 | 3.05 | 4.0 | 17 | 2.37 | 1.8 | 2.2 | 2.05 | 3.25 | 5.7 |
| 2 | 2.45 | 2.25 | 1.85 | 2.15 | 3.05 | 4.35 | 18 | 2.37 | 1.8 | 2.25 | 2.1 | 3.25 | 5.6 |
| 3 | 2.45 | 2.2 | 1.9 | 2.1 | 3.0 | 4.8 | 19 | 2.37 | 1.8 | 2.25 | 2.1 | 3.25 | 5.5 |
| 4 | 2.45 | 2.2 | 2.0 | 2.1 | 2.9 | 4.95 | 20 | 2.3 | 1.8 | 2.3 | 2.1 | 3.25 | 5.45 |
| 5 | 2.4 | 2.19 | 2.1 | 2.05 | 2.9 | 5.35 | 21 | 2.35 | 1.8 | 2.3 | 2.15 | 3.25 | 5.4 |
| 6 | 2.38 | 2.0 | 2.2 | 2.0 | 2.9 | 5.45 | 22 | 2.33 | 1.8 | 2.3 | 2.2 | 3.25 | 5.4 |
| 7 | 2.4 | 1.95 | 2.0 | 2.0 | 2.95 | 5.5 | 23 | 2.32 | 1.7 | 2.3 | 2.3 | 3.2 | 5.35 |
| 8 | 2.48 | 1.9 | 2.05 | 2.0 | 3.0 | 5.6 | 24 | 2.35 | 1.8 | 2.32 | 2.4 | 3.15 | 5.3 |
| 9 | 2.47 | 1.9 | 2.1 | 2.0 | 3.0 | 5.8 | 25 | 2.48 | 1.8 | 2.35 | 2.55 | 3.15 | 5.3 |
| 10 | 2.45 | 1.9 | 2.05 | 1.95 | 3.15 | 5.0 | 26 | 2.4 | 1.8 | 2.32 | 2.8 | 3.1 | 5.28 |
| 11 | 2.42 | 1.85 | 2.15 | 1.95 | 3.25 | 6.1 | 27 | 2.35 | 1.85 | 2.3 | 2.95 | 3.15 | 5.25 |
| 12 | 2.4 | 1.85 | 2.25 | 2.05 | 3.25 | 6.25 | 28 | 2.3 | 1.8 | 2.3 | 3.0 | 3.2 | 5.2 |
| 13 | 2.4 | 1.8 | 2.25 | 1.98 | 3.3 | 6.25 | 29 | 2.3 | ..... | 2.25 | 3.05 | 3.3 | 5.1 |
| 14 | 2.38 | 1.8 | 2.3 | 2.0 | 3.25 | 6.15 | 30 | 2.28 | ..... | 2.2 | 3.1 | 3.5 | 5.0 |
| 15 | 2.37 | 1.8 | 2.2 | 2.0 | 3.27 | 6.0 | 31 | 2.25 | ..... | 2.2 | ..... | 3.8 | ..... |
| 16 | 2.35 | 1.8 | 2.2 | 2.0 | 3.25 | 5.9 | | | | | | | |

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## CHELAN RIVER BELOW LAKE CHELAN, WASHINGTON.

This station was established November 6, 1903, by G. H. Bliss. It is located at the highway bridge 3,000 feet below the outlet of the lake and in the town of Chelan. A dam which has been constructed at the foot of the lake by the town of Chelan holds back the flow of water to some extent during the dry season. This dam is about 3,000 feet above the bridge.

The channel is straight for 50 feet above and 150 feet below the station. The right bank can not overflow. The left bank is lower than the right, but is not liable to overflow. Both banks are without trees. The bed of the stream is composed of rocks and gravel, free from vegetation, and liable to shift somewhat.

Discharge measurements are now made from the downstream side of the upper highway bridge. The initial point for soundings is the end vertical on the downstream side of the bridge at the northwest approach.

The gage is a vertical rod 16 feet long attached to the third pile bent of the northwestern approach to the bridge. During 1905 the gage was read once each day by G. L. Richardson. The bench mark is a wire spike driven into a root on the west side of a large cottonwood tree, which is 40 feet downstream from the northwestern approach to the bridge and 30 feet from the river; elevation, 11.86 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 387; 135, pp 68-69.
Discharge: 100, p 387; 135, p 69.
Discharge, monthly: 135, p 71.
Gage heights: 100, p 387; 135, pp 69-70.
Rating table: 135, p 70.

*Discharge measurements of Chelan River below Lake Chelan, Washington, in 1905.*

| Date. | Hydrographer. | Width. | Area of section | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| May 4 | O. Laurgaard | 285 | 943 | 4.04 | 7.68 | 3,810 |
| November 4 | do. | 295 | 1,129 | 1.09 | 6.20 | 1,230 |
| November 27 | W. C. Sawyer | 292 | 1,117 | .87 | 5.65 | 970 |

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*Daily gage height, in feet, of Chelan River below Lake Chelan, Washington, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.4 | 5.3 | 5.4 | 6.75 | 7.8 | 8.9 | 9.5 | 8.0 | 5.9 | 6.2 | 6.3 | 5.55 |
| 2 | 5.4 | 5.3 | 5.4 | 6.7 | 7.8 | 9.2 | 9.43 | 7.9 | 5.85 | 6.23 | 6.25 | 5.6 |
| 3 | 5.45 | 5.3 | 5.43 | 6.65 | 7.75 | 9.4 | 9.38 | 7.8 | 5.85 | 6.35 | 6.25 | 5.6 |
| 4 | 5.4 | 5.29 | 5.48 | 6.65 | 7.65 | 9.6 | 9.35 | 7.7 | 5.8 | 6.55 | 6.2 | 5.6 |
| 5 | 5.4 | 5.29 | 5.52 | 6.62 | 7.65 | 9.85 | 9.3 | 7.6 | 5.78 | 6.6 | 6.15 | 5.55 |
| 6 | 5.4 | 5.5 | 5.56 | 6.6 | 7.65 | 9.95 | 9.28 | 7.55 | 5.8 | 6.7 | 6.13 | 5.5 |
| 7 | 5.4 | 5.45 | 5.57 | 6.6 | 7.7 | 10.0 | 9.22 | 7.5 | 5.85 | 6.9 | 6.1 | 5.5 |
| 8 | 5.38 | 5.45 | 6.15 | 6.6 | 7.75 | 10.1 | 9.15 | 7.55 | 5.9 | 6.8 | 6.1 | 5.5 |
| 9 | 5.38 | 5.45 | 6.18 | 6.6 | 7.75 | 10.2 | 9.1 | 7.5 | 6.0 | 6.75 | 6.1 | 5.5 |
| 10 | 5.37 | 5.45 | 6.5 | 6.58 | 7.9 | 10.35 | 9.05 | 7.4 | 6.1 | 6.6 | 6.05 | 5.5 |
| 11 | 5.37 | 5.4 | 6.6 | 6.58 | 8.0 | 10.45 | 9.0 | 7.35 | 6.12 | 6.65 | 6.0 | 5.45 |
| 12 | 5.37 | 5.4 | 6.65 | 6.65 | 8.0 | 10.6 | 8.95 | 7.3 | 6.15 | 6.7 | 5.98 | 5.4 |
| 13 | 5.37 | 5.4 | 6.65 | 6.6 | 8.05 | 10.6 | 8.9 | 7.3 | 6.18 | 6.75 | 5.9 | 5.5 |
| 14 | 5.35 | 5.38 | 6.75 | 6.6 | 8.0 | 10.55 | 8.8 | 7.25 | 6.2 | 6.6 | 5.88 | 5.5 |
| 15 | 5.35 | 5.4 | 6.8 | 6.6 | 8.02 | 10.4 | 8.7 | 7.15 | 6.2 | 6.55 | 5.85 | 5.5 |
| 16 | 5.35 | 5.4 | 6.8 | 6.6 | 8.0 | 10.3 | 8.6 | 6.6 | 6.15 | 6.5 | 5.9 | 5.5 |
| 17 | 5.38 | 5.4 | 6.8 | 6.65 | 8.0 | 10.15 | 8.5 | 6.6 | 6.15 | 6.48 | 5.8 | 5.5 |
| 18 | 5.38 | 5.4 | 6.9 | 6.7 | 8.0 | 10.05 | 8.37 | 5.7 | 6.1 | 6.4 | 5.8 | 5.5 |
| 19 | 5.32 | 5.4 | 6.9 | 6.7 | 8.0 | 10.0 | 8.25 | 5.75 | 6.05 | 6.38 | 5.9 | 5.45 |
| 20 | 5.32 | 5.4 | 6.95 | 6.7 | 8.0 | 9.95 | 8.2 | 5.75 | 6.0 | 6.32 | 5.9 | 5.4 |
| 21 | 5.33 | 5.4 | 6.95 | 6.77 | 8.0 | 9.9 | 8.17 | 5.75 | 6.1 | 6.1 | 5.85 | 5.4 |
| 22 | 5.33 | 5.4 | 6.95 | 6.85 | 8.0 | 9.85 | 8.2 | 5.78 | 6.1 | 6.25 | 5.8 | 5.4 |
| 23 | 5.32 | 5.37 | 6.95 | 7.0 | 8.0 | 9.85 | 8.25 | 5.78 | 6.1 | 6.2 | 5.7 | 5.4 |
| 24 | 5.32 | 5.4 | 7.03 | 7.1 | 7.95 | 9.8 | 8.25 | 5.8 | 6.2 | 6.25 | 5.65 | 5.4 |
| 25 | 5.35 | 5.4 | 7.03 | 7.3 | 7.9 | 9.8 | 8.25 | 5.8 | 6.2 | 6.2 | 5.7 | 5.4 |
| 26 | 5.32 | 5.4 | 7.02 | 7.6 | 7.85 | 9.78 | 8.25 | 5.85 | 6.18 | 6.25 | 5.8 | 5.6 |
| 27 | 5.33 | 5.4 | 7.0 | 7.7 | 7.9 | 9.75 | 8.22 | 5.8 | 6.18 | 6.35 | 5.7 | 5.5 |
| 28 | 5.32 | 5.4 | 7.0 | 7.75 | 7.95 | 9.7 | 8.2 | 5.8 | 6.2 | 6.3 | 5.65 | 5.45 |
| 29 | 5.32 | ..... | 6.9 | 7.8 | 8.05 | 9.6 | 8.17 | 5.8 | 6.2 | 6.3 | 5.6 | 5.4 |
| 30 | 5.3 | ..... | 6.8 | 7.85 | 8.2 | 9.58 | 8.15 | 6.0 | 6.2 | 6.35 | 5.6 | 5.4 |
| 31 | 5.3 | ..... | 6.8 | ..... | 8.6 | ..... | 8.1 | 5.9 | ..... | 6.3 | ..... | 5.4 |

NOTE.—No ice record.

*Station rating table for Chelan River below Lake Chelan, Washington, from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 5.30 | 780 | 6.50 | 1,650 | 7.70 | 3,630 | 8.80 | 5,690 |
| 5.40 | 820 | 6.60 | 1,780 | 7.80 | 3,810 | 8.90 | 5,880 |
| 5.50 | 865 | 6.70 | 1,920 | 7.90 | 3,990 | 9.00 | 6,070 |
| 5.60 | 915 | 6.80 | 2,070 | 8.00 | 4,170 | 9.20 | 6,450 |
| 5.70 | 965 | 6.90 | 2,230 | 8.10 | 4,360 | 9.40 | 6,830 |
| 5.80 | 1,020 | 7.00 | 2,390 | 8.20 | 4,550 | 9.60 | 7,210 |
| 5.90 | 1,080 | 7.10 | 2,560 | 8.30 | 4,740 | 9.80 | 7,600 |
| 6.00 | 1,150 | 7.20 | 2,730 | 8.40 | 4,930 | 10.00 | 8,000 |
| 6.10 | 1,230 | 7.30 | 2,910 | 8.50 | 5,110 | 10.20 | 8,400 |
| 6.20 | 1,320 | 7.40 | 3,090 | 8.60 | 5,300 | 10.40 | 8,800 |
| 6.30 | 1,420 | 7.50 | 3,270 | 8.70 | 5,500 | 10.60 | 9,200 |
| 6.40 | 1,530 | 7.60 | 3,450 | | | | |

The above table is applicable only for open-channel conditions. It is based on nine discharge measurements made during 1904-5. It is fairly well defined between gage heights 5.6 feet and 10.3 feet.

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*Estimated monthly discharge of Chelan River below Lake Chelan, Washington, for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 842 | 780 | 803 | 49,380 |
| February | 865 | 776 | 817 | 45,370 |
| March | 2,441 | 820 | 1,809 | 111,200 |
| April | 3,900 | 1,754 | 2,239 | 133,200 |
| May | 5,300 | 3,540 | 4,049 | 249,000 |
| June | 9,200 | 5,880 | 7,887 | 469,380 |
| July | 7,020 | 4,360 | 5,471 | 336,400 |
| August | 4,170 | 965 | 2,180 | 134,000 |
| September | 1,320 | 1,009 | 1,207 | 71,820 |
| October | 2,230 | 1,230 | 1,608 | 98,870 |
| November | 1,508 | 915 | 1,115 | 66,350 |
| December | 915 | 820 | 856 | 52,630 |
| The year | 9,200 | 776 | 2,503 | 1,818,000 |

## WENATCHEE RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Wenatchee River has its source on the eastern slope of the Cascade Mountains, and flows southeastward through Wenatchee Lake, entering Columbia River near Wenatchee, Wash.

### WENATCHEE RIVER AT CASHMERE, WASH.

This station was established July 26, 1904, by W. G. Steward. It is located at the highway bridge just north of the town of Cashmere, Wash.

The channel is curved for about 800 feet above and below the station, and the current is swift. The right bank is high, gravelly and rocky, lined with timber and bushes, and not liable to overflow. The left bank is not high, but overflows only in extremely high water. The bed of the stream is covered with small rounded bowlders and cobblestones, is free from vegetation, and permanent. The channel is divided by the pier into two channels. The bridge is located about midway of a long, sweeping curve. The water is swift, especially at the middle of the south span.

Discharge measurements are made from the downstream side of the two-span bridge to which the gage is attached. The initial point for soundings is a bolthead in the southeast corner of the bridge, marked zero.

A plain-staff gage is fastened to the downstream edge of the south face of the middle pier. During 1905 the gage was read once each day by A. C. Jones. Bench marks were established as follows: (1) The head of an 8-penny nail driven into a timber at the southeast corner of the middle pier; elevation, 12.98 feet. (2) A bolthead at the southeast corner of the bridge, identical with the initial point; elevation, 16.63 feet. (3) A railroad spike driven into a telephone pole at the left end of the bridge; elevation, 10.91 feet. Elevations refer to the datum of the gage.

A description of this station and gage height and discharge data are contained in Water-Supply Paper No. 135, United States Geological Survey, pages 71–72.

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*Discharge measurements of Wenatchee River at Cashmere, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| October 30 | W. G. Steward | 187 | 960 | 2.31 | 2.90 | 2,220 |
| November 3 | do | 185 | 894 | 2.23 | 2.48 | 1,993 |
| November 14 | do | 164 | 799 | 1.70 | 1.98 | 1,357 |
| November 25 | do | 162 | 784 | 1.55 | 1.87 | 1,214 |

*Daily gage height, in feet, of Wenatchee River at Cashmere, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.8 | 1.1 | 2.5 | 3.1 | 4.5 | 6.9 | 5.0 | 2.9 | 1.6 | 1.9 | 2.6 | 1.9 |
| 2 | 1.8 | 1.1 | 2.8 | 3.0 | 4.3 | 7.0 | 4.9 | 2.9 | 1.6 | 1.9 | 2.5 | 1.9 |
| 3 | 1.8 | 1.2 | 3.7 | 2.9 | 4.2 | 7.0 | 5.0 | 2.9 | 1.6 | 3.9 | 2.5 | 2.0 |
| 4 | 1.8 | 1.3 | 4.1 | 2.9 | 4.1 | 7.1 | 4.9 | 2.8 | 1.6 | 5.5 | 2.5 | 1.9 |
| 5 | 1.7 | 1.3 | 4.2 | 2.8 | 4.1 | 6.6 | 4.8 | 2.7 | 1.6 | 4.3 | 2.4 | 1.8 |
| 6 | 1.5 | 1.3 | 4.2 | 3.0 | 4.3 | 6.3 | 4.7 | 2.6 | 1.6 | 4.5 | 2.3 | 1.9 |
| 7 | 1.5 | 1.4 | 4.1 | 3.1 | 4.6 | 6.2 | 4.5 | 2.5 | 1.6 | 4.2 | 2.3 | 1.8 |
| 8 | 1.5 | 1.3 | 4.1 | 3.2 | 5.1 | 6.3 | 4.4 | 2.5 | 1.6 | 3.9 | 2.2 | 1.9 |
| 9 | 1.5 | 1.2 | 4.2 | 3.3 | 5.5 | 6.7 | 4.5 | 2.5 | 1.9 | 3.5 | 2.2 | 1.8 |
| 10 | 1.4 | 1.1 | 4.4 | 3.3 | 5.3 | 6.9 | 4.6 | 2.6 | 2.0 | 3.2 | 2.1 | 1.7 |
| 11 | 1.3 | 1.0 | 4.6 | 3.3 | 5.0 | 6.9 | 4.5 | 2.5 | 1.9 | 3.1 | 2.1 | 1.6 |
| 12 | 1.3 | 1.8 | 4.6 | 3.4 | 4.8 | 6.7 | 4.3 | 2.5 | 1.8 | 3.0 | 2.1 | 1.5 |
| 13 | 1.4 | 1.8 | 4.3 | 3.6 | 4.8 | 6.4 | 4.1 | 2.4 | 1.8 | 2.8 | 2.0 | 1.4 |
| 14 | 1.4 | 1.8 | 4.1 | 3.7 | 4.8 | 5.9 | 3.8 | 2.4 | 1.7 | 2.7 | 2.0 | 1.4 |
| 15 | 1.4 | 1.8 | 4.0 | 3.6 | 5.0 | 5.6 | 3.6 | 2.3 | 1.7 | 2.7 | 2.0 | 1.4 |
| 16 | 1.5 | 1.8 | 3.9 | 3.6 | 4.9 | 5.5 | 3.4 | 2.2 | 1.6 | 2.6 | 1.9 | 1.4 |
| 17 | 1.5 | 1.8 | 4.0 | 3.5 | 4.8 | 5.3 | 3.3 | 2.1 | 1.5 | 2.5 | 1.9 | 1.5 |
| 18 | 1.6 | 1.8 | 4.3 | 3.5 | 4.8 | 5.2 | 3.3 | 2.1 | 1.5 | 2.4 | 2.0 | 1.6 |
| 19 | 1.5 | 1.8 | 4.3 | 3.6 | 4.7 | 5.3 | 3.2 | 2.1 | 1.5 | 2.3 | 2.1 | 1.6 |
| 20 | 1.5 | 1.7 | 4.2 | 3.8 | 4.6 | 5.5 | 3.3 | 2.0 | 1.5 | 2.2 | 2.1 | 1.5 |
| 21 | 1.5 | 1.6 | 4.2 | 4.0 | 4.5 | 5.5 | 3.4 | 2.0 | 1.7 | 2.2 | 2.0 | 1.5 |
| 22 | 1.4 | 1.5 | 4.1 | 4.2 | 4.4 | 5.6 | 3.6 | 1.9 | 1.9 | 2.1 | 2.0 | 1.4 |
| 23 | 1.4 | 1.4 | 4.0 | 4.7 | 4.3 | 5.6 | 3.7 | 2.1 | 1.9 | 2.1 | 1.9 | 1.3 |
| 24 | 1.5 | 1.5 | 3.9 | 5.35 | 4.2 | 5.5 | 3.8 | 1.8 | 1.8 | 2.1 | 1.9 | 1.4 |
| 25 | 1.5 | 1.8 | 3.8 | 6.1 | 4.1 | 5.4 | 3.6 | 1.7 | 1.8 | 4.0 | 1.9 | 1.4 |
| 26 | 1.4 | 2.3 | 3.8 | 6.25 | 4.2 | 5.4 | 3.5 | 1.7 | 1.8 | 4.1 | 2.0 | 1.5 |
| 27 | 1.5 | 2.4 | 3.6 | 6.0 | 4.6 | 5.3 | 3.4 | 1.7 | 2.5 | 3.7 | 2.1 | 1.5 |
| 28 | 1.6 | 2.4 | 3.5 | 5.6 | 5.1 | 5.4 | 3.3 | 1.7 | 2.2 | 3.3 | 2.0 | 1.5 |
| 29 | 1.5 | ..... | 3.4 | 5.1 | 5.6 | 5.0 | 3.2 | 1.7 | 2.1 | 3.3 | 1.9 | 1.5 |
| 30 | 1.4 | ..... | 3.3 | 4.8 | 5.8 | 4.9 | 3.0 | 1.7 | 2.0 | 3.1 | 1.9 | 1.5 |
| 31 | 1.2 | ..... | 3.1 | ..... | 6.3 | ..... | 3.0 | 1.7 | ..... | 2.8 | ..... | 1.4 |

NOTE.—Ice conditions during part of January and February.



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*Station rating table for Wenatchee River at Cashmere, Wash., from July 27, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.00 | 550 | 2.30 | 1,665 | 3.60 | 3,240 | 4.90 | 5,150 |
| 1.10 | 615 | 2.40 | 1,770 | 3.70 | 3,380 | 5.00 | 5,300 |
| 1.20 | 685 | 2.50 | 1,875 | 3.80 | 3,520 | 5.20 | 5,620 |
| 1.30 | 755 | 2.60 | 1,985 | 3.90 | 3,660 | 5.40 | 5,940 |
| 1.40 | 830 | 2.70 | 2,095 | 4.00 | 3,800 | 5.60 | 6,260 |
| 1.50 | 910 | 2.80 | 2,210 | 4.10 | 3,950 | 5.80 | 6,580 |
| 1.60 | 990 | 2.90 | 2,330 | 4.20 | 4,100 | 6.00 | 6,900 |
| 1.70 | 1,075 | 3.00 | 2,450 | 4.30 | 4,250 | 6.20 | 7,240 |
| 1.80 | 1,165 | 3.10 | 2,580 | 4.40 | 4,400 | 6.40 | 7,580 |
| 1.90 | 1,260 | 3.20 | 2,710 | 4.50 | 4,550 | 6.60 | 7,920 |
| 2.00 | 1,360 | 3.30 | 2,840 | 4.60 | 4,700 | 6.80 | 8,260 |
| 2.10 | 1,460 | 3.40 | 2,970 | 4.70 | 4,850 | 7.00 | 8,600 |
| 2.20 | 1,560 | 3.50 | 3,100 | 4.80 | 5,000 | | |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904–5. It is well defined between gage heights 1.8 feet and 3.9 feet.

*Estimated monthly discharge of Wenatchee River at Cashmere, Wash., for 1904 and 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| 1904. | | | | |
| July 27-31 | 3,660 | 2,970 | 3,354 | 33,260 |
| August | 2,970 | 1,360 | 2,078 | 127,800 |
| September | 1,560 | 830 | 1,122 | 66,760 |
| October | 1,360 | 685 | 851 | 52,330 |
| November | 1,985 | 615 | 1,120 | 66,640 |
| December | 1,665 | 1,075 | 1,331 | 81,840 |
| The period | | | | 428,600 |
| 1905. | | | | |
| January | 1,165 | 685 | 915 | 56,260 |
| February | 1,770 | 550 | 1,001 | 55,590 |
| March | 4,700 | 1,875 | 3,702 | 227,600 |
| April | 7,325 | 2,210 | 3,794 | 225,800 |
| May | 7,410 | 3,950 | 4,940 | 303,800 |
| June | 8,780 | 5,150 | 6,872 | 408,900 |
| July | 5,300 | 2,450 | 3,727 | 229,200 |
| August | 2,330 | 1,075 | 1,610 | 99,000 |
| September | 1,875 | 910 | 1,133 | 67,420 |
| October | 6,100 | 1,260 | 2,660 | 163,600 |
| November | 1,985 | 1,260 | 1,476 | 87,830 |
| December | 1,360 | 755 | 993 | 61,060 |
| The year | 8,780 | 550 | 2,735 | 1,986,000 |

NOTE.—Rating table applied as for open channel during entire year.

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## YAKIMA RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Yakima River has its source in Keechelus Lake, on the eastern slope of the Cascade Mountains, in Kittitas County, Wash. Within a short distance it receives the water of Kachess Lake, and 2½ miles above Clealum it receives the outlet of the last of the three large headwater lakes. Practically its entire summer flow is now used for irrigation. It enters Columbia River 5 miles above Kennewick, Wash.

Naches River has its source on the eastern slope of the Cascade Mountains, in Yakima County, Wash. It flows in a general southeasterly direction, entering Yakima River a short distance above North Yakima. Irrigation is practiced in the narrow valley along the lower course of the river, and its waters are of greater value for the irrigation of lands west of North Yakima. The river has considerable fall, and the water can easily be diverted by means of comparatively short canals.

Tieton River is the principal tributary of Naches River and discharges into the latter about 17 miles above its junction with Yakima River, near North Yakima. Its source is in the Cascade Mountains in the vicinity of Cowlitz Pass. A peculiar feature of the stream is the turbid, milk-white appearance of the water. It is similar in this respect to White River, on the western slope of the Cascade Range. The water of South Fork of the Tieton, 25 miles above the mouth, is, however, perfectly clear. The forks head in the glaciers of a peak of the Cascades known as Goat Rock.

### YAKIMA RIVER NEAR MARTIN, WASH.

Lake Keechelus is the uppermost of the three lakes forming the source of Yakima River. At the outlet a good dam site exists, and by the construction of a dam a considerable portion of the flow of the Yakima at this point can be stored and used for irrigation in the lower Yakima Valley during the dry season.

A gaging station was established October 18, 1903, by G. H. Bliss. It is 1,000 feet below the outlet of Lake Keechelus, 800 feet below the dam of the Cascade Lumber Company, and 4 miles northwest of Martin, Wash.

The channel is straight for 500 feet above and 350 feet below the station. Both banks are high, not liable to overflow, and heavily timbered. The current is swift, and there is but one channel at all stages. The bed of the stream is composed of gravel and is free from vegetation and permanent.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The cable has a total span of 200 feet. The initial point for soundings is the north face of the tree on the south (right) bank, to which the cable is fastened.

The original gage was in two sections and was located on the right bank just above the cable. The lower inclined section read from 5 to 7 feet. The upper vertical section read from 7 to 13 feet. Observations were taken daily from this gage until November 14, 1903, when the gage was destroyed by the caving of the river bank. Observations were then discontinued until January 28, 1904, when a new vertical gage, No. 2, was installed by the Yakima Development Company at a point 75 feet above the location of the old gage, and readings were resumed by the United States Geological Survey. The datum of this gage which is now in use is 0.07 foot higher than the original one. The gage is a vertical rod fastened to an overhanging tree. During 1905 the gage was read twice each day by Christian Hansen. Bench marks were established as follows: (1) The top of a spike in the root on the north side of a large cedar tree 50 feet south and 50 feet west of the gage; elevation, 21.59 feet. (2) A nail in the base of a 48-inch fir tree on the right bank 25 feet above the cable and 50 feet from the river; the tree is blazed and marked "B. M.;" elevation, 25.22 feet. Elevations refer to the datum of the present gage.

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Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 386; 135, p 74.
Discharge: 100, p 386; 135, p 75.
Discharge, monthly: 135, p 76.
Gage heights: 135, p 75.
Rating table: 135, p 76.

*Discharge measurements of Yakima River near Martin, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 5 | W. J. Lightfoot | 120 | 344 | 2.46 | 8.60 | 846 |
| June 28 | do | 118 | 251 | 1.52 | 7.60 | 381 |
| August 25 | W. C. Muldrow | 105 | 130 | .59 | 6.50 | 78 |
| November 16 | do | 108 | 179 | .80 | 6.87 | 1,430 |

*Daily gage height, in feet, of Yakima River near Martin, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.1 | 6.8 | 7.5 | 7.3 | 7.9 | 8.8 | 7.4 | 6.6 | 6.4 | 6.91 | 7.34 | 7.24 |
| 2 | 7.2 | 6.8 | 7.8 | 7.2 | 7.8 | 8.75 | 7.4 | 6.6 | 6.4 | 7.15 | 7.28 | 7.22 |
| 3 | 7.2 | 6.8 | 7.9 | 7.1 | 7.7 | 8.85 | 7.3 | 6.6 | 6.42 | 7.94 | 7.23 | 7.2 |
| 4 | 7.1 | 6.75 | 8.0 | 7.1 | 7.7 | 8.65 | 7.3 | 6.55 | 6.42 | 8.28 | 7.23 | 7.14 |
| 5 | 7.1 | 6.75 | 8.2 | 7.1 | 7.6 | 8.45 | 7.3 | 6.5 | 6.4 | 8.32 | 7.19 | 7.12 |
| 6 | 7.0 | 6.75 | 8.25 | 7.1 | 7.7 | 8.35 | 7.2 | 6.5 | 6.39 | 8.37 | 7.14 | 7.12 |
| 7 | 7.0 | 6.78 | 8.2 | 7.2 | 7.8 | 8.3 | 7.15 | 6.5 | 6.4 | 8.23 | 7.10 | 7.1 |
| 8 | 6.9 | 6.8 | 8.1 | 7.2 | 8.1 | 8.3 | 7.1 | 6.5 | 6.4 | 8.17 | 7.06 | 7.08 |
| 9 | 6.9 | 6.8 | 8.15 | 7.2 | 8.3 | 8.3 | 7.1 | 6.5 | 6.4 | 8.09 | 7.04 | 7.04 |
| 10 | 6.8 | 6.8 | 8.25 | 7.2 | 8.2 | 8.25 | 7.1 | 6.5 | 6.4 | 7.94 | 7.01 | 7.02 |
| 11 | 6.8 | 6.75 | 8.3 | 7.2 | 8.1 | 8.2 | 7.1 | 6.5 | 6.39 | 7.82 | 7.0 | 6.98 |
| 12 | 6.8 | 6.7 | 8.3 | 7.25 | 8.0 | 8.1 | 7.0 | 6.4 | 6.39 | 7.71 | 6.94 | 6.96 |
| 13 | 6.8 | 6.65 | 8.15 | 7.3 | 8.0 | 8.0 | 7.0 | 6.4 | 6.42 | 7.62 | 6.92 | 6.92 |
| 14 | 6.8 | 6.65 | 8.0 | 7.4 | 8.25 | 7.9 | 6.9 | 6.4 | 6.4 | 7.56 | 6.9 | 6.9 |
| 15 | 6.8 | 6.65 | 7.9 | 7.4 | 8.4 | 7.8 | 6.9 | 6.5 | 6.4 | 7.52 | 6.89 | 6.88 |
| 16 | 6.8 | 6.6 | 7.9 | 7.4 | 8.3 | 7.7 | 6.9 | 6.5 | 6.4 | 7.46 | 6.87 | 6.86 |
| 17 | 6.8 | 6.6 | 7.9 | 7.4 | 8.3 | 7.6 | 6.9 | 6.55 | 6.42 | 7.44 | 6.85 | 6.92 |
| 18 | 6.7 | 6.6 | 7.9 | 7.4 | 8.2 | 7.6 | 6.8 | 6.6 | 6.43 | 7.4 | 6.88 | 6.94 |
| 19 | 6.7 | 6.6 | 7.9 | 7.5 | 8.1 | 7.55 | 6.8 | 6.6 | 6.42 | 7.32 | 6.9 | 6.92 |
| 20 | 6.7 | 6.6 | 7.9 | 7.65 | 8.0 | 7.5 | 6.8 | 6.6 | 6.44 | 7.26 | 6.98 | 6.9 |
| 21 | 6.7 | 6.7 | 7.9 | 7.8 | 7.9 | 7.5 | 6.8 | 6.6 | 6.43 | 7.22 | 6.94 | 6.86 |
| 22 | 6.7 | 6.7 | 7.9 | 7.9 | 7.9 | 7.45 | 6.8 | 6.5 | 6.44 | 7.17 | 6.92 | 6.85 |
| 23 | 6.7 | 6.7 | 7.9 | 8.15 | 7.9 | 7.4 | 6.7 | 6.5 | 6.5 | 7.11 | 6.9 | 6.86 |
| 24 | 6.8 | 6.8 | 7.9 | 8.45 | 7.95 | 7.4 | 6.7 | 6.5 | 6.5 | 7.26 | 6.88 | 6.85 |
| 25 | 6.8 | 6.9 | 7.8 | 8.75 | 8.05 | 7.4 | 6.7 | 6.5 | 6.52 | 8.04 | 6.9 | 6.88 |
| 26 | 6.8 | 7.1 | 7.7 | 8.8 | 8.1 | 7.4 | 6.7 | 6.5 | 6.74 | 8.09 | 6.96 | 6.92 |
| 27 | 6.8 | 7.2 | 7.6 | 8.7 | 8.1 | 7.45 | 6.7 | 6.5 | 6.84 | 7.97 | 7.02 | 6.95 |
| 28 | 6.8 | 7.2 | 7.6 | 8.5 | 8.4 | 7.5 | 6.7 | 6.5 | 6.87 | 7.82 | 7.16 | 6.94 |
| 29 | 6.9 | ..... | 7.5 | 8.25 | 8.5 | 7.5 | 6.7 | 6.5 | 6.9 | 7.72 | 7.32 | 6.92 |
| 30 | 6.8 | ..... | 7.4 | 8.0 | 8.5 | 7.5 | 6.6 | 6.5 | 6.91 | 7.56 | 7.31 | 6.9 |
| 31 | 6.8 | ..... | 7.3 | ..... | 8.9 | ..... | 6.6 | 6.4 | ..... | 7.44 | ..... | 6.88 |

NOTE.—No ice record.

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*Station rating table for Yakima River near Martin, Wash., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 6.30 | 58 | 7.00 | 178 | 7.70 | 430 | 8.40 | 748 |
| 6.40 | 67 | 7.10 | 208 | 7.80 | 472 | 8.50 | 798 |
| 6.50 | 78 | 7.20 | 240 | 7.90 | 516 | 8.60 | 848 |
| 6.60 | 90 | 7.30 | 274 | 8.00 | 560 | 8.70 | 898 |
| 6.70 | 106 | 7.40 | 310 | 8.10 | 606 | 8.80 | 950 |
| 6.80 | 126 | 7.50 | 348 | 8.20 | 652 | 8.90 | 1,004 |
| 6.90 | 150 | 7.60 | 388 | 8.30 | 700 | 9.00 | 1,058 |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903–1905 It is well defined.

*Estimated monthly discharge of Yakima River near Martin, Wash., for 1905.*

[Drainage area, 56 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 240 | 106 | 143 | 8,793 | 2.55 | 2.94 |
| February | 240 | 90 | 124 | 6,887 | 2.21 | 2.30 |
| March | 700 | 274 | 522 | 32,100 | 9.32 | 10.74 |
| April | 950 | 208 | 419 | 24,930 | 7.48 | 8.34 |
| May | 1,004 | 388 | 603 | 37,080 | 10.77 | 12.42 |
| June | 977 | 310 | 534 | 31,780 | 9.54 | 10.64 |
| July | 310 | 90 | 169 | 10,390 | 3.02 | 3.48 |
| August | 90 | 67 | 79.7 | 4,901 | 1.42 | 1.64 |
| September | 153 | 66 | 80.9 | 4,814 | 1.44 | 1.61 |
| October | 734 | 153 | 430 | 26,440 | 7.68 | 8.85 |
| November | 288 | 138 | 191 | 11,360 | 3.41 | 3.80 |
| December | 254 | 138 | 173 | 10,640 | 3.09 | 3.56 |
| The year | 1,004 | 66 | 289 | 210,100 | 5.16 | 70.32 |

## YAKIMA RIVER NEAR NORTH YAKIMA, WASH.

This station was established May 5, 1904, by G. H. Bliss, and was discontinued October 15, 1905. It is located at the highway bridge at Selah Gap, 2¼ miles north of North Yakima, Wash., one-fourth mile above the confluence of Yakima and Naches rivers, and 300 feet east of the bridge of the Northern Pacific Railway.

The channel is straight for about 800 feet above and 600 feet below the station. The current is sluggish at low stages. Both banks are low, partly wooded, and subject to overflow during high water. The bed of the stream is composed of gravel and sand, and is free from vegetation, and stable. There is one channel at all stages, broken by three bridge piers.

Discharge measurements are made from the downstream side of the bridge. The initial point for soundings is a point marked zero on the top railing near the right end of the bridge, downstream side.

A staff gage is fastened vertically to the south side of the pier at the right end of the four-span highway bridge. During 1905 the gage was read once each day by Patrick Gallagher. The bench mark is the top of the shoe plate on the lower side of the bridge above the pier nearest the right bank; elevation, 16.64 feet above the datum of the gage.

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A description of this station, with gage heights, discharge data, and rating table, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 79–81.

*Daily gage height, in feet, of Yakima River near North Yakima, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Day. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 4.4 | 2.6 | 2.3 | ..... | 17 | 4.7 | 3.0 | 2.4 | ..... | ..... |
| 2 | 6.3 | ..... | 2.6 | 2.3 | 2.8 | 18 | ..... | 2.9 | 2.4 | 2.2 | ..... |
| 3 | 6.5 | 4.2 | 2.6 | 2.3 | 2.8 | 19 | 4.4 | 2.9 | 2.4 | 2.2 | ..... |
| 4 | ..... | 4.1 | 2.6 | 2.3 | 3.6 | 20 | 4.2 | 2.8 | 2.3 | 2.2 | ..... |
| 5 | 6.8 | 4.0 | 2.5 | 2.3 | 4.2 | 21 | 4.2 | 2.8 | 2.3 | 2.2 | ..... |
| 6 | 6.7 | 3.9 | 2.5 | 2.3 | 4.5 | 22 | 4.2 | 2.8 | 2.3 | 2.3 | ..... |
| 7 | 6.3 | 3.7 | 2.5 | 2.2 | 4.6 | 23 | 4.3 | 2.75 | 2.3 | 2.3 | ..... |
| 8 | 5.8 | 3.5 | 2.5 | 2.2 | ..... | 24 | 4.3 | 2.7 | 2.3 | ..... | ..... |
| 9 | 5.7 | 3.5 | 2.5 | 2.2 | 4.3 | 25 | ..... | 2.7 | 2.3 | 2.3 | ..... |
| 10 | 5.7 | 3.4 | 2.5 | 2.2 | 4.0 | 26 | 4.3 | 2.7 | 2.3 | 2.4 | ..... |
| 11 | ..... | 3.4 | 2.5 | 2.2 | 4.0 | 27 | 4.3 | 2.7 | ..... | 2.4 | ..... |
| 12 | 5.6 | 3.3 | 2.5 | 2.2 | 3.9 | 28 | 4.9 | 2.7 | 2.3 | 2.5 | ..... |
| 13 | 5.4 | 3.2 | ..... | 2.3 | 3.8 | 29 | 4.7 | 2.7 | 2.3 | 2.6 | ..... |
| 14 | 5.2 | 3.0 | 2.4 | 2.3 | 3.8 | 30 | 4.6 | 2.65 | 2.3 | 2.8 | ..... |
| 15 | 4.9 | 3.0 | 2.4 | 2.3 | ..... | 31 | ..... | 2.6 | 2.3 | ..... | ..... |
| 16 | 4.8 | 3.0 | 2.4 | 2.2 | ..... | | | | -- | | |

## YAKIMA RIVER NEAR YAKIMA, WASH.

Yakima River enters Columbia River just above the town of Pasco. The first measurement of the river was made at this point August 14, 1893. The station was originally located at the county bridge at Union Gap, 2 miles below Yakima, Wash. The station was reestablished in August, 1895, a cable and new gage being installed about 1,000 feet below the bridge. It is about 3 miles above the intake of the Sunnyside canal. The station is of value, as it is the only point near the large irrigated area above and below which is unaffected by the taking out of water in irrigating canals.

The channel is straight for 1,000 feet above and below the station. The current has a moderate velocity. The right bank is high, not liable to overflow, and is covered with sagebrush. The left bank is a low gravel bar which overflows during extreme high water. The bed of the stream is composed of gravel and is free from vegetation and permanent. There is one channel at low water and two channels at ordinary and flood stages.

Discharge measurements are made by means of a cable, car, and tagged wire. The initial point for soundings is a cross chiseled on a rock 2.7 feet from the cable support on the right bank.

The present gage is an inclined rod attached to a willow stump and post set in the ground. During 1905 the gage was read once each day by Hugh Kennedy. Bench marks were established as follows: (1) The top of a large bowlder between two other bowlders 43 feet north of the gage and 6.5 feet east of the fence; elevation, 17.52 feet. (2) The top of a large bowlder under the railroad fence 12 feet north of the gage; elevation, 21.29 feet. (3) The initial point for soundings; elevation, 17.45 feet. The bench marks are marked "B. M." with black paint. Elevations refer to the datum of the gage.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; Bull=Bulletin; WS=Water-Supply Paper):

Description: Ann 14, ii, pp 133–134; 18, iv, pp 356–357; 19, iv, p 479; Bull 140, pp 245–246; WS 16, p 175; 28, p 159; 38, pp 373–374; 51, p 441; 66, p 135; 85, pp 188–189; 100, pp 376–377; 135, pp 81–82.

Discharge. Ann 14, ii, p 134; 18, iv, p 357; 19, iv, p 480; Bull 131, pp 90, 92; 140, p 246; WS 16, p 175; 28, p 109; 38, p 374; 51, p 441; 85, p 189; 100, p 377; 135, p 83.

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**Discharge, monthly:** Ann 18, iv, p 358; 19, iv, p 480; 20, iv, pp 499, 500; 21, iv, p 427; 22, iv, p 447; WS p 75, 202; 85, p 190; 100, p 378; 135, p 84.

**Discharge, yearly:** Ann 20, iv, p 62.

**Gage heights:** Bull 140, p 247; WS 11, p 85; 16, p 175; 28, p 165; 38, p 374; 51, p 442; 66, p 135; 85, p 189; 100, p 377; 135, p 83.

**Hydrographs:** Ann 19, iv, pp 480, 481; 20, iv, p 501; 21, iv, p 428; 22, iv, p 447.

**Rainfall and run-off relation:** Ann 20, iv, p 500.

**Rating tables:** Ann 18 iv, p. 357; 19, iv, p. 479; WS 28, p. 170; 39, p. 451; 52, p. 522; 66, p. 177; 85, p 190; 100, p 378; 135, p 84.

*Discharge measurements of Yakima River near Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 19 | W. J. Lightfoot | 236 | 1,344 | 2.92 | 6.10 | 3,922 |
| September 2 | W. C. Muldrow | 230 | 753 | 1.04 | 3.64 | 780 |
| October 26 | do | 240 | 1,250 | 2.85 | 5.60 | 3,567 |
| November 18 | Sawyer and Muldrow | 238 | 960 | 1.67 | 4.32 | 1,600 |

*Daily gage height, in feet, of Yakima River near Yakima, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.0 | 4.3 | 6.0 | 6.0 | 6.9 | 7.7 | 6.5 | 4.1 | 3.6 | 4.1 | 5.1 | 4.7 |
| 2 | 5.0 | 4.4 | 6.8 | 5.9 | 6.5 | 7.9 | 6.4 | 4.1 | 3.6 | 4.15 | 5.0 | 4.7 |
| 3 | 5.0 | 4.5 | 7.2 | 5.8 | 6.1 | 8.3 | 6.3 | 4.1 | 3.6 | 4.15 | 4.9 | 4.6 |
| 4 | 5.0 | 4.6 | 7.8 | 5.8 | 6.0 | 9.1 | 6.3 | 4.0 | 3.6 | 5.1 | 4.9 | 4.65 |
| 5 | 4.9 | 4.5 | 7.8 | 5.9 | 6.0 | 8.8 | 6.0 | 4.0 | 3.6 | 5.8 | 4.8 | 4.7 |
| 6 | 4.9 | 4.4 | 7.9 | 5.9 | 6.0 | 8.3 | 6.0 | 4.0 | 3.65 | 6.4 | 4.8 | 4.7 |
| 7 | 4.9 | 4.5 | 7.9 | 6.0 | 6.1 | 8.0 | 5.9 | 3.9 | 3.68 | 6.45 | 4.7 | 4.7 |
| 8 | 4.9 | 4.6 | 7.9 | 6.0 | 6.3 | 7.8 | 5.7 | 3.9 | 3.68 | 6.4 | 4.7 | 4.75 |
| 9 | 4.9 | 4.6 | 7.7 | 5.9 | 6.4 | 7.6 | 5.4 | 3.8 | 3.62 | 6.0 | 4.6 | 4.65 |
| 10 | 4.8 | 4.5 | 7.9 | 5.8 | 7.0 | 7.6 | 5.3 | 3.8 | 3.62 | 5.9 | 4.6 | 4.5 |
| 11 | 4.6 | 4.4 | 7.9 | 5.8 | 7.0 | 7.6 | 5.3 | 3.7 | 3.68 | 5.8 | 4.6 | 4.45 |
| 12 | 4.4 | 4.0 | 7.8 | 5.9 | 6.7 | 7.5 | 5.1 | 3.7 | 3.7 | 5.8 | 4.55 | 4.45 |
| 13 | 4.4 | 3.9 | 7.9 | 5.9 | 6.5 | 7.5 | 5.1 | 3.7 | 3.7 | 5.8 | 4.5 | 4.45 |
| 14 | 4.4 | 3.9 | 7.9 | 6.1 | 6.3 | 7.3 | 4.9 | 3.7 | 3.8 | 5.4 | 4.5 | 4.4 |
| 15 | 4.2 | 3.9 | 7.6 | 6.2 | 6.4 | 7.2 | 4.9 | 3.6 | 3.75 | 5.3 | 4.4 | 4.4 |
| 16 | 4.4 | 3.8 | 7.3 | 6.1 | 6.6 | 6.9 | 4.7 | 3.6 | 3.7 | 5.2 | 4.4 | 4.3 |
| 17 | 4.6 | 3.8 | 7.3 | 6.0 | 6.7 | 6.5 | 4.6 | 3.6 | 3.7 | 5.15 | 4.35 | 4.3 |
| 18 | 4.7 | 3.8 | 7.3 | 6.0 | 6.6 | 6.5 | 4.6 | 3.6 | 3.72 | 5.0 | 4.35 | 4.35 |
| 19 | 4.7 | 3.9 | 7.4 | 6.0 | 6.6 | 6.4 | 4.5 | 3.6 | 3.7 | 5.0 | 4.4 | 4.3 |
| 20 | 4.7 | 4.0 | 7.5 | 6.0 | 6.5 | 6.3 | 4.4 | 3.6 | 3.7 | 4.9 | 4.45 | 4.3 |
| 21 | 4.7 | 4.9 | 7.4 | 5.9 | 6.4 | 6.3 | 4.4 | 3.7 | 3.72 | 4.9 | 4.45 | 4.35 |
| 22 | 4.6 | 5.2 | 7.3 | 6.0 | 6.2 | 6.3 | 4.4 | 3.6 | 3.8 | 4.8 | 4.4 | 4.35 |
| 23 | 4.6 | 5.5 | 7.2 | 6.3 | 6.2 | 6.3 | 4.3 | 3.6 | 3.8 | 4.7 | 4.4 | 4.3 |
| 24 | 4.7 | 5.5 | 7.2 | 6.8 | 6.2 | 6.3 | 4.4 | 3.6 | 3.8 | 4.7 | 4.4 | 4.3 |
| 25 | 4.7 | 5.4 | 7.1 | 7.4 | 6.2 | 6.4 | 4.3 | 3.6 | 3.8 | 4.7 | 4.3 | 4.35 |
| 26 | 4.7 | 5.4 | 7.0 | 7.8 | 6.1 | 6.7 | 4.2 | 3.6 | 3.8 | 5.0 | 4.4 | 4.4 |
| 27 | 4.8 | 5.4 | 6.9 | 8.0 | 6.1 | 7.0 | 4.3 | 3.6 | 3.78 | 5.8 | 4.5 | 4.4 |
| 28 | 4.9 | 5.9 | 6.6 | 7.9 | 6.4 | 6.9 | 4.2 | 3.6 | 3.9 | 5.8 | 4.6 | 4.3 |
| 29 | 4.8 | ..... | 6.4 | 7.3 | 6.7 | 6.7 | 4.2 | 3.6 | 4.0 | 5.7 | 4.7 | 4.3 |
| 30 | 4.7 | ..... | 6.3 | 7.0 | 6.7 | 6.7 | 4.2 | 3.6 | 4.0 | 5.6 | 4.7 | 4.2 |
| 31 | 4.5 | ..... | 6.3 | ..... | 7.4 | ..... | 4.1 | 3.6 | ..... | 5.2 | ..... | 4.2 |

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## YAKIMA RIVER AT PROSSER, WASH.

This station was established May 30, 1904, by G. H. Bliss. It is located at the highway bridge 600 feet below Prosser Falls at Prosser, Wash.

The channel is straight for about 100 feet above and 600 feet below the station. The current above the station is swift, the foot of the rapids being 150 feet above. The current below the station is sluggish at ordinary and swift at higher stages. Both banks are high and not subject to overflow. The bed of the stream is composed of rock and is free from vegetation and permanent. There are large bowlders in the channel. There is but one channel at all stages, broken by the trestle bents on either side during the higher stages.

Discharge measurements are made from the downstream side of the bridge, which has a single span with trestle approach at either end. The initial point for soundings is a nail driven into the downstream guard rail 30 feet from the right bank.

A standard chain gage is attached to the upstream side of the bridge near the right bank; length of the chain, 28.06 feet. During 1905 the gage was read once each day by J. N. Jacoby. Bench marks were established as follows: (1) A spike in a sill on the east end of the pump of the Prosser Irrigation Company's canal; elevation, 13.87 feet. (2) A spike on an upright bridge timber 20 feet south of the steel and concrete pier on the south bank; elevation, 11.42 feet. (3) The top of the steel cylinder of the concrete pier at the right bank, upstream side; elevation, 23.92 feet. Elevations refer to the datum of the gage.

A description of this station, with gage heights, discharge data, and rating table is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 85–87.

*Discharge measurements of Yakima River at Prosser, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 17 | Bliss and Muldrow | ..... | ..... | ..... | 0.55 | [a] 194 |
| September 1 | G. H. Bliss | ..... | ..... | ..... | .43 | [a] 176 |
| October 22 | W. C. Muldrow | 130 | 1,102 | 1.77 | 3.76 | [b] 1,950 |

[a] Discharge of river is found by adding the sum of the measured discharges of the power flumes to the estimated discharge of the river below the dam and subtracting the discharge of the pumps:

| | Aug. 17. | Sept. 1. |
|---|---|---|
| Prosser flume | 185 | 105 |
| Taylor flume | 0 | 58 |
| Estimated for river | 20 | 20 |
| | 205 | 183 |
| Discharge of pumps | 9 | 7 |
| Flow at gage | 194 | 176 |

[b] Measured at the bridge.

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*Daily gage height, in feet, of Yakima River at Prosser, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|
| 1 | ..... | 5.76 | 1.76 | 0.43 | 1.93 | 4.26 | 3.93 |
| 2 | ..... | 5.6 | 1.68 | .51 | 1.76 | 4.43 | 3.85 |
| 3 | ..... | 5.51 | 1.68 | .51 | 2.01 | 4.43 | 3.85 |
| 4 | ..... | 5.43 | 1.6 | .51 | 2.51 | 4.18 | 3.85 |
| 5 | ..... | 5.18 | 1.51 | .55 | 3.93 | 4.1 | 3.76 |
| 6 | ..... | 4.93 | 1.43 | .51 | 5.1 | 4.1 | 3.85 |
| 7 | ..... | 4.6 | 1.43 | .51 | 5.43 | 3.93 | 3.76 |
| 8 | 7.81 | 4.43 | 1.35 | .55 | 5.6 | 3.76 | 3.68 |
| 9 | 7.68 | 4.18 | 1.26 | .68 | 5.26 | 3.76 | 3.68 |
| 10 | 7.68 | 3.93 | 1.1 | .68 | 5.01 | 3.68 | 3.68 |
| 11 | 7.77 | 3.76 | .93 | .68 | 4.85 | 3.6 | 3.6 |
| 12 | 7.81 | 3.43 | .76 | .85 | 4.6 | 3.6 | 3.51 |
| 13 | 7.43 | 3.3 | .6 | 1.26 | 4.43 | 3.68 | 3.43 |
| 14 | 7.18 | 3.3 | .51 | 1.01 | 4.26 | 3.68 | 3.35 |
| 15 | 6.93 | 3.1 | .51 | 1.18 | 4.18 | 3.6 | 3.26 |
| 16 | 6.35 | 2.93 | .51 | 1.26 | 4.01 | 3.6 | 3.43 |
| 17 | 6.18 | 2.8 | .51 | 1.01 | 3.93 | 3.68 | 3.43 |
| 18 | 6.75 | 2.68 | .51 | 1.26 | 3.85 | 3.51 | 3.51 |
| 19 | 5.68 | 2.6 | .51 | 1.26 | 3.85 | 3.43 | 3.51 |
| 20 | 5.6 | 2.43 | .51 | 1.26 | 3.76 | 3.43 | 3.51 |
| 21 | 5.64 | 2.18 | .51 | 1.35 | 3.68 | 3.51 | 3.43 |
| 22 | 5.51 | 2.43 | .51 | 1.35 | 3.76 | 3.51 | 3.43 |
| 23 | 5.51 | 2.1 | .47 | 1.35 | 3.68 | 3.51 | 3.35 |
| 24 | 5.6 | 2.18 | .51 | 1.6 | 3.43 | 3.43 | 3.35 |
| 25 | 5.6 | 2.1 | .55 | 1.51 | 3.51 | 3.43 | 3.18 |
| 26 | 5.6 | 1.93 | .55 | 1.51 | 3.60 | 3.43 | 3.18 |
| 27 | 5.68 | 1.85 | .51 | 1.68 | 4.93 | 3.51 | 3.1 |
| 28 | 6.1 | 1.85 | .81 | 1.76 | 5.01 | 3.76 | 3.18 |
| 29 | 6.18 | 1.85 | .43 | 1.93 | 4.76 | 3.93 | 3.35 |
| 30 | 6.01 | 1.85 | .43 | 1.93 | 4.68 | 3.93 | 3.43 |
| 31 | ..... | 1.68 | .43 | ..... | 4.43 | ..... | ..... |

NOTE.—Low-water estimates for this station may be obtained by taking the sum of the flow of Yakima River at Kiona; the Kiona Canal and Kiona Water-Supply Canal.

## YAKIMA RIVER AT KIONA, WASH.

This station was established August 20, 1895. It is located at the highway bridge on the county road about 1,800 feet northwest of the Northern Pacific Railway station at Kiona, Wash. It is about 23 miles above the mouth of the river.

The channel is straight for 500 feet above and 400 feet below the station. The current has a moderate velocity. The right bank is low, but is well protected by a levee and is not subject to overflow. The bed of the stream is composed of fine gravel, not subject to change. At low water the river flows beneath the middle main span; at high water it passes under an additional shorter span at each end of the bridge.

Discharge measurements are made from the upstream side of the bridge, to which the gage is attached. There is a stay wire 70 feet above the bridge. The initial point for soundings is a point on the west side of the bridge 100 feet south of the center of the south pier of the main span.

The original gage consisted of an inclined and a vertical section, spiked to the east end of the south pier of the bridge and anchored with rocks. The gage used during 1905 up to December 23 was of the wire type, and was located on the downstream side of the bridge between the fifth and seventh verticals from the right bank; length of the wire, 27.21 feet. The distance from the end of the scale board to the outside edge of the pulley was 2.00 feet.

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December 23, 1905, a staff gage was installed, consisting of a vertical section bolted to the downstream side of the pier near the right bank and an inclined section at the foot of the pier. During 1905 the gage was read once each day by H. A. Shandy. Bench marks were established as follows: (1) The top of a spike in the east end of the cap of the first trestle bent on the right bank; elevation, 20.94 feet. (2) A spike on the north side of the stay-wire post on the right bank; elevation, 18.73 feet. (3) A nail in the upstream end of the first trestle bent on the left bank; elevation, 18.73 feet. Elevations refer to the datum of the gage. The United States Geological Survey standard iron bench-mark post, near the Northern Pacific Railway station, has an elevation above sea level of 515 feet, 62.00 feet above the datum of the gage. All bench marks are marked "B. M." with black paint.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann = Annual Report; Bull = Bulletin; WS = Water-Supply Paper):

Description: Ann 18, iv, p 358; 19, iv, p 481; Bull 140, p 248; WS 16, p 176; 28, p 159; 38, p 375; 51, p 442; 66, p 136; 85, p 186; 100, pp 373–374; 135, pp 87–88.

Discharge: Ann 18, iv, p 358; 19, iv, p 483; Bull 140, p 248; WS 16, p 176; 28, p 169; 38, p 375; 51, p 442; 66, p 136; 85, p 186; 100, p 374; 135, p 88.

Discharge, monthly: Ann 18, iv, p 359; 19, iv, p 485; 20, iv, pp 499, 502; 21, iv, p 428; 22, iv, p 448; WS 75, p 203; 85, p 188; 100, p 375; 135, p 89.

Discharge, yearly: Ann 20, iv, p 62.

Gage heights: Bull 140, p 249; WS 11, p 83; 16, p 176; 28, p 165; 38, p 375; 51, p 443; 66, p 136; 85, p 187; 100, p 374; 135, p 88.

Hydrographs: Ann 19, iv, p 486; 20, iv, p 502; 21, iv, p 429; 22, iv, p 448; WS 75, p 203.

Rainfall and run-off relation: Ann 20, iv, p 500.

Rating tables: Ann 18, iv, p 359; 19, iv, p 484; WS 28, p 170; 39, p 454; 52, p 522; 66, p 177; 85, p 187; 100, p 375; 135, p 89.

*Discharge measurements of Yakima River at Kiona, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| May 10 | W. J. Lightfoot | 253 | 1,527 | 3.49 | 7.50 | 5,327 |
| June 12 | do | 298 | 2,008 | 4.67 | 8.80 | 9,377 |
| August 24 | W. C. Muldrow | 62 | 70 | 2.63 | 2.60 | 183 |
| September 14 | Frank Halfpenny | 205 | 531 | .57 | 2.90 | 305 |
| September 14[a] | do | 125 | 128 | 2.26 | 2.90 | 290 |
| October 19 | W. C. Muldrow | 217 | 1,063 | 2.19 | 5.15 | 2,337 |
| October 22 | do | 130 | 1,102 | 1.77 | 4.76 | 1,950 |
| November 22 | Muldrow and Sawyer | 248 | 1,008 | 1.89 | 5.05 | 1,905 |

[a] Made above rapids.

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*Daily gage height, in feet, of Yakima River at Kiona, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.81 | 4.9 | 6.65 | 6.9 | 7.5 | 8.2 | 6.8 | 3.35 | 2.4 | 3.7 | 5.6 | 5.3 |
| 2 | 5.65 | 4.85 | 7.0 | 6.7 | 7.2 | 8.9 | 6.7 | 3.3 | 2.45 | 3.75 | 5.5 | 5.3 |
| 3 | 5.6 | 4.8 | 7.62 | 6.6 | 6.8 | 9.3 | 6.6 | 3.35 | 2.45 | 3.8 | 5.4 | 5.3 |
| 4 | 5.55 | 4.85 | 8.48 | 6.4 | 6.5 | 9.9 | 6.4 | 3.25 | 2.4 | 3.9 | 5.4 | 5.3 |
| 5 | 5.55 | 4.9 | 8.95 | 6.2 | 6.4 | 10.4 | 6.1 | 3.2 | 2.4 | 4.7 | 5.3 | 5.3 |
| 6 | 5.56 | 4.9 | 9.25 | 6.1 | 6.3 | 9.9 | 6.0 | 3.2 | 2.45 | 5.75 | 5.3 | 5.2 |
| 7 | 5.4 | 4.85 | 9.38 | 6.0 | 6.2 | 9.5 | 5.8 | 3.1 | 2.5 | 6.6 | 5.2 | 5.15 |
| 8 | 5.4 | 4.8 | 9.25 | 6.3 | 6.3 | 9.0 | 5.5 | 3.0 | 2.55 | 6.7 | 5.15 | 5.15 |
| 9 | 5.48 | 4.82 | 9.1 | 6.2 | 6.8 | 8.6 | 5.3 | 3.0 | 2.7 | 6.8 | 5.15 | 5.1 |
| 10 | 5.2 | 4.65 | 9.2 | 6.3 | 7.5 | 8.8 | 5.1 | 2.8 | 2.8 | 6.2 | 5.2 | 5.1 |
| 11 | 5.1 | 4.7 | 9.3 | 6.3 | 7.5 | 8.9 | 5.0 | 2.7 | 2.8 | 6.0 | 5.15 | 5.05 |
| 12 | 4.4 | 4.3 | 9.45 | 6.2 | 7.3 | 8.8 | 4.9 | 2.5 | 2.8 | 5.7 | 5.1 | 5.05 |
| 13 | 4.4 | 4.48 | 9.4 | 6.15 | 6.4 | 8.3 | 4.8 | 2.7 | 2.85 | 5.6 | 5.1 | 5.0 |
| 14 | 4.5 | 4.25 | 9.15 | 6.3 | 6.7 | 7.9 | 4.7 | 2.6 | 2.85 | 5.4 | 5.1 | 5.0 |
| 15 | 5.0 | 4.45 | 8.8 | 6.5 | 6.6 | 7.7 | 4.65 | 2.5 | 2.9 | 5.4 | 5.06 | 5.0 |
| 16 | 5.0 | 4.5 | 8.55 | 6.5 | 6.8 | 7.4 | 4.5 | 2.4 | 3.0 | 5.35 | 5.0 | 5.0 |
| 17 | 5.2 | 4.6 | 8.6 | 6.4 | 7.0 | 7.1 | 4.2 | 2.4 | 3.0 | 5.3 | 4.9 | 5.0 |
| 18 | 5.2 | 4.6 | 8.65 | 6.3 | 6.9 | 6.9 | 4.0 | 2.5 | 3.0 | 5.2 | 4.9 | 4.95 |
| 19 | 5.3 | 4.6 | 8.75 | 6.3 | 6.9 | 6.7 | 4.0 | 2.6 | 3.0 | 5.2 | 5.0 | 4.95 |
| 20 | 5.3 | 4.7 | 8.7 | 6.3 | 6.8 | 6.5 | 3.9 | 2.6 | 3.2 | 5.1 | 4.9 | 4.95 |
| 21 | 5.0 | 4.7 | 8.65 | 6.45 | 6.5 | 6.5 | 3.7 | 2.6 | 3.1 | 5.0 | 5.0 | 5.05 |
| 22 | 4.98 | 5.5 | 8.6 | 6.75 | 6.6 | 6.4 | 3.4 | 2.55 | 3.1 | 5.0 | 5.0 | 5.1 |
| 23 | 4.9 | 5.9 | 8.4 | 7.0 | 6.5 | 6.4 | 3.8 | 2.6 | 3.15 | 5.0 | 5.05 | 5.2 |
| 24 | 4.88 | 5.9 | 8.2 | 7.2 | 6.5 | 6.4 | 4.0 | 2.5 | 3.2 | 5.0 | 5.0 | 4.85 |
| 25 | 4.92 | 5.78 | 8.0 | 7.8 | 6.4 | 6.6 | 3.8 | 2.5 | 3.3 | 4.9 | 4.95 | 4.85 |
| 26 | 4.96 | 5.82 | 8.0 | 8.55 | 6.4 | 6.5 | 3.7 | 2.5 | 3.3 | 5.0 | 4.9 | 4.9 |
| 27 | 5.0 | 6.3 | 7.9 | 9.2 | 6.2 | 6.4 | 3.5 | 2.5 | 3.35 | 5.8 | 5.0 | 4.95 |
| 28 | 4.95 | 6.5 | 7.6 | 9.0 | 6.4 | 6.7 | 3.4 | 2.5 | 3.4 | 6.2 | 5.1 | 5.0 |
| 29 | 5.2 | ..... | 7.58 | 8.5 | 6.7 | 6.9 | 3.3 | 2.5 | 3.5 | 6.3 | 5.3 | 5.0 |
| 30 | 5.15 | ..... | 7.25 | 8.2 | 7.3 | 7.1 | 3.35 | 2.55 | 3.6 | 6.4 | 5.3 | 4.95 |
| 31 | 5.2 | ..... | 7.0 | ..... | 7.8 | ..... | 3.30 | 2.4 | ..... | 5.8 | ..... | 4.95 |

*Station rating table for Yakima River at Kiona, Wash., from January 1, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.40 | 142 | 3.90 | 835 | 5.40 | 2,420 | 7.80 | 6,940 |
| 2.50 | 164 | 4.00 | 910 | 5.50 | 2,560 | 8.00 | 7,400 |
| 2.60 | 188 | 4.10 | 990 | 5.60 | 2,700 | 8.20 | 7,870 |
| 2.70 | 215 | 4.20 | 1,070 | 5.70 | 2,850 | 8.40 | 8,350 |
| 2.80 | 245 | 4.30 | 1,160 | 5.80 | 3,000 | 8.60 | 8,830 |
| 2.90 | 280 | 4.40 | 1,250 | 5.90 | 3,160 | 8.80 | 9,320 |
| 3.00 | 315 | 4.50 | 1,350 | 6.00 | 3,320 | 9.00 | 9,820 |
| 3.10 | 355 | 4.60 | 1,450 | 6.20 | 3,650 | 9.20 | 10,320 |
| 3.20 | 395 | 4.70 | 1,560 | 6.40 | 3,990 | 9.40 | 10,840 |
| 3.30 | 440 | 4.80 | 1,670 | 6.60 | 4,350 | 9.60 | 11,360 |
| 3.40 | 490 | 4.90 | 1,780 | 6.80 | 4,740 | 9.80 | 11,880 |
| 3.50 | 555 | 5.00 | 1,900 | 7.00 | 5,160 | 10.00 | 12,400 |
| 3.60 | 620 | 5.10 | 2,020 | 7.20 | 5,600 | 10.20 | 12,920 |
| 3.70 | 690 | 5.20 | 2,150 | 7.40 | 6,040 | 10.40 | 13,450 |
| 3.80 | 760 | 5.30 | 2,280 | 7.60 | 6,480 | | |

The above table is applicable only for open-channel conditions. It is based on 16 discharge measurements made during 1902–1905. It is well defined.

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*Estimated monthly discharge of Yakima River at Kiona, Wash., for 1905.*

[Drainage area, 5,230 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 3,016 | 1,250 | 2,126 | 130,700 | 0.407 | 0.469 |
| February | 4,170 | 1,115 | 1,972 | 109,500 | .377 | .393 |
| March | 10,970 | 4,445 | 8,477 | 521,200 | 1.62 | 1.87 |
| April | 10,320 | 3,320 | 4,998 | 297,400 | .956 | 1.07 |
| May | 6,940 | 3,650 | 4,720 | 290,200 | .902 | 1.04 |
| June | 13,450 | 3,990 | 7,143 | 425,100 | 1.37 | 1.53 |
| July | 4,740 | 440 | 1,757 | 108,000 | .336 | .387 |
| August | 465 | 142 | 240 | 14,760 | .046 | .053 |
| September | 620 | 142 | 304 | 18,090 | .058 | .065 |
| October | 4,740 | 690 | 2,522 | 155,100 | .482 | .556 |
| November | 2,700 | 1,780 | 2,071 | 123,200 | .396 | .442 |
| December | 2,280 | 1,725 | 1,980 | 121,800 | .379 | .437 |
| The year | 13,450 | 142 | 3,192 | 2,315,000 | .611 | 8.31 |

## CANALS IN YAKIMA VALLEY, WASHINGTON.

Nowhere in the State of Washington has irrigation been practiced longer or have matters pertaining to irrigation reached a higher state of development than in Yakima Valley. The rapid fall of the rivers, the great fertility of the soil, and the climatic conditions have all served to bring this about.

The chief sources of water supply for irrigation canals are Yakima and Naches rivers. The Naches, when it joins the Yakima, has already received the water of the Tieton. Besides these rivers, Wenas, Cowiche, Atanum, Toppenish, and Satus creeks, with some small creeks in the vicinity of Ellensburg, irrigate large areas of land lying in the valleys through which they flow. About 100,000 acres of land are at present under irrigation from these sources, and with the available storage reservoirs at the heads of Yakima, Naches, and Tieton rivers, it is probable that 300,000 acres additional could be irrigated, if the water were used economically.

There are at the present time about 50 irrigating canals in operation in Yakima Valley, which obtain their water from the sources above mentioned and irrigate the low land lying near the streams. This land is of volcanic origin and very fertile. Where water is applied large and very profitable crops of fruit, hay, hops, and grain are raised.

A large area of the best quality of land in Yakima Valley remains unirrigated, but the available water supply, especially at low stages of the streams, is practically exhausted, so that the irrigation of additional land is dependent on the feasibility of storing water, to be used during about two and one-half months of the irrigation season.

There are five reservoir sites available in the Yakima region. These are Lake Clealum, Lake Kachess, and Lake Keechelus, at the head of Yakima River, having a combined capacity of about 370,000 acre-feet; Bumping Lake, at the head of Naches River, with a storage capacity of 22,000 acre-feet, and McAlisters Meadows, on Tieton River, with a storage capacity of 35,000 acre-feet, giving a total of about 427,000 acre-feet, which is enough to maintain a flow of 2,300 second-feet for a period of two and one-half months, or during the dry portion of the irrigation season. This amount of water, with a liberal allowance for loss in transmission, could easily be made to irrigate 150,000 acres of land and might be made to irrigate, with economical use, much more than this amount.

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The canals at present in operation in Yakima Valley are mostly in the hands of stock companies and with but few exceptions furnish the farmers under them water enough to supply all demands. Most farmers have taken from the ditches as much water as seemed most convenient for their use; this in many instances has been far in excess of the amount actually needed to irrigate their land economically and profitably. The results of this excessive use of water are only too apparent to those who have traveled through the oldest irrigated sections of Yakima Valley. Land that was once valuable is now water-logged and worthless, alkali being everywhere visible.

The following table gives a list of canals on which observations were made during the irrigation season of 1905. The results of measurements of canals and ditches in Yakima Valley made during 1904 are contained in Water-Supply Paper No. 135, United States Geological Survey.

*Canals taking water from Yakima River.*

| Canal. | Location. | | | | Bank of river. | Length in miles. |
|---|---|---|---|---|---|---|
| | Nearest town. | Head works. | | | | |
| | | Section. | Township. | Range. | | |
| *Below Clealum River and above Naches River.* | | | | | | |
| Cascade | Thorp | ..... | 19 N. | 17 E. | Left | 42½ |
| West Kittitas | ....do | 33 | 19 N. | 17 E. | Right | 14 |
| Town | Ellensburg | 7 | 18 N. | 17 E. | Left | 30 |
| Olsen | ....do | 18 | 18 N. | 18 E. | ...do | ..... |
| Fogarty | ....do | ..... | ..... | ..... | Right | ..... |
| Selah Moxee | North Yakima | 8 | 14 N. | 19 E. | Left | 27 |
| Taylor | ....do | ..... | ..... | ..... | Right | 4½ |
| *Below Naches River and above Atanum Creek.* | | | | | | |
| Moxee | North Yakima | 7 | 13 N. | 19 E. | Left | 8 |
| Hubbard | ....do | 7 | 13 N. | 19 E. | ...do | 7 |
| Fowler | ....do | 18 | 13 N. | 19 E. | ...do | 8½ |
| Granger | ....do | 18 | 13 N. | 19 E. | ...do | ..... |
| *Below Atanum Creek.* | | | | | | |
| New Reservation No. 2 | Yakima | 17 | 12 N. | 19 E. | Right | (a) |
| Old Reservation No. 1 | ....do | 28 | 12 N. | 19 E. | ...do | 12½ |
| Sunnyside | ....do | 28 | 12 N. | 19 E. | Left | 38 |
| Benton Water Co | Kiona | ..... | ..... | ..... | ...do | ..... |
| Kiona | ....do | 10 | 9 N. | 26 E. | ...do | 9 |
| Kiona Water Supply Co | ....do | ..... | ..... | ..... | ...do | ..... |
| Kennewick | Kennewick | 3 | 10 N. | 27 E. | Right | 39½ |
| Grosscup's | Kiona | 3 | 10 N. | 27 E. | Left | 5½ |

[a] Not completed. Proposed length, 65 miles.

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*Canals taking water from Naches River.*

| Canal. | Location. | | | | Bank of river. | Length in miles. |
|---|---|---|---|---|---|---|
| | Nearest town. | Head works. Section. | Township. | Range. | | |
| Selah Valley | North Yakima | 35 | 15 N. | 16 E. | Left | 20 |
| *Below Tieton River and above Cowiche Creek.* | | | | | | |
| Wapatox | North Yakima | 36 | 15 N. | 16 E. | Left | 16 |
| Cox | do | 6 | 14 N. | 17 E. | Right | |
| Upper Scott | do | 4 | 14 N. | 17 E. | do | |
| Lower Scott | do | 9 | 14 N. | 17 E. | do | |
| Fortune | do | 9 | 14 N. | 17 E. | do | |
| Laswell | do | 14 | 14 N. | 17 E. | do | |
| Yakima Valley | do | 24 | 14 N. | 17 E. | do | 22 |
| Clark | do | | 14 N. | 17 E. | Left | |
| Lowry | do | | 14 N. | 17 E. | do | |
| Kelly | do | | 14 N. | 17 E. | do | |
| Gleed | do | 24 | 14 N. | 17 E. | do | 6 |
| Morrisey | do | 25 | 14 N. | 17 E. | do | |
| White and Leach | do | | | | do | |
| McCormick | do | | | | do | |
| Shearer-Chapman | do | | | | do | |
| Nelson | do | | | | do | |
| Naches-Cowiche | do | 9 | 13 N. | 18 E. | Right | 7 |
| *Below Cowiche Creek.* | | | | | | |
| Broadgauge | North Yakima | 10 | 13 N. | 18 E. | Right | 3 |
| Power | do | 10 | 13 N. | 18 E. | do | 1 |
| Shanno-Fruitvale | do | 10 | | | do | |
| Shanno | do | 11 | 13 N. | 18 E. | do | 8 |
| Union | do | 11 | 13 N. | 18 E. | do | 8½ |
| Town | do | 12 | 13 N. | 18 E. | do | |

### CASCADE CANAL NEAR THORP, WASH.

This is the first canal taking water from Yakima River. It heads in the river on its left bank in sec. 33, T. 19 N., R. 17 E., about 5½ miles above Thorp.

The gage is at the headgates. Measurements are made in a flume one-half mile below the gage.

*Discharge measurements of Cascade canal near Thorp, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 6 | W. C. Muldrow | 19.2 | 4.19 | 3.0 | 80.0 |
| July 14 | do | 16.0 | 3.81 | 2.65 | 61.0 |
| August 29 | do | 15.6 | 3.77 | 2.65 | 59.0 |
| October 6 | do | 8.0 | 2.61 | 1.6 | 20.9 |

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*Daily gage height, in feet, of Cascade canal near Thorp, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2.65 | 2.5 | 2.6 | 12 | 2.9 | 2.3 | 2.6 | 2.6 | 22 | 2.7 | 2.6 | 2.6 | 2.55 |
| 2 | | 2.65 | 2.6 | 2.6 | 13 | 2.9 | 2.2 | 2.6 | 2.6 | 23 | 2.7 | 2.6 | 2.7 | 2.6 |
| 3 | | 2.65 | 2.7 | 2.6 | 14 | 2.9 | 2.15 | 2.6 | 2.6 | 24 | 2.7 | 2.6 | 2.7 | 2.6 |
| 4 | | 2.6 | 2.6 | 2.6 | 15 | 2.8 | 2.1 | 2.55 | 2.6 | 25 | 2.7 | 2.65 | 2.7 | 2.65 |
| 5 | | 2.5 | 2.65 | 2.6 | 16 | 2.8 | 2.1 | 2.5 | 2.6 | 26 | 2.7 | 2.65 | 2.6 | 2.65 |
| 6 | | 2.5 | 2.5 | 2.6 | 17 | 2.7 | 2.1 | 2.6 | 2.55 | 27 | 2.7 | 2.6 | 2.6 | 2.7 |
| 7 | 3.0 | 2.45 | 2.5 | 2.6 | 18 | 2.7 | 2.1 | 2.6 | 2.5 | 28 | 2.7 | 2.6 | 2.7 | 2.7 |
| 8 | 3.0 | 2.4 | 2.45 | 2.6 | 19 | 2.7 | 2.6 | 2.7 | 2.5 | 29 | 2.7 | 2.6 | 2.65 | 2.8 |
| 9 | 3.0 | 2.3 | 2.6 | 2.6 | 20 | 2.7 | 2.6 | 2.7 | 2.6 | 30 | 2.7 | 2.6 | 2.6 | 2.9 |
| 10 | 3.0 | 2.3 | 2.55 | 2.6 | 21 | 2.7 | 2.6 | 2.7 | 2.6 | 31 | | 2.5 | 2.6 | |
| 11 | 3.0 | 2.3 | 2.6 | 2.6 | | | | | | | | | | |

### WEST KITTITAS CANAL NEAR THORP, WASH.

This canal heads in Yakima River on its right bank in sec. 33, T. 19 N., R. 17 E., about 3 miles northwest of Thorp.

The gage is attached to a bridge 1½ miles below the head works. Measurements are made from the bridge.

*Discharge measurements of West Kittitas canal near Thorp, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet* | *Second-feet.* |
| June 30 | W. C. Muldrow | 12.0 | 1.17 | 1.10 | 14.0 |
| July 10 | do | 27.8 | 1.80 | 2.15 | 50.5 |
| August 29 | do | 33.5 | 2.27 | 2.55 | 73.7 |

*Daily gage height, in feet, of West Kittitas canal near Thorp, Wash., for 1905.*

| Day. | July. | Aug. | Sept. | Day. | July. | Aug. | Sept. | Day. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.1 | 2.5 | 2.5 | 12 | 2.1 | 2.5 | 2.5 | 22 | 2.4 | 2.5 | 0.3 |
| 2 | 1.1 | 2.5 | 2.5 | 13 | 2.1 | 2.5 | 2.6 | 23 | 2.4 | 2.6 | .3 |
| 3 | 1.4 | 2.5 | 2.5 | 14 | 2.2 | 2.5 | 2.6 | 24 | 2.4 | 2.6 | 2.2 |
| 4 | 1.9 | 2.5 | 2.5 | 15 | 2.2 | 2.5 | 2.6 | 25 | 2.4 | 2.6 | |
| 5 | 1.9 | 2.5 | 2.5 | 16 | 2.4 | 2.5 | 2.5 | 26 | 2.4 | 2.5 | |
| 6 | 1.9 | 2.5 | 2.5 | 17 | 2.3 | 2.5 | 1.8 | 27 | 2.4 | 2.5 | |
| 7 | 2.0 | 2.5 | 2.6 | 18 | 2.3 | 2.5 | .4 | 28 | 2.5 | 2.5 | .7 |
| 8 | 1.9 | 2.5 | 2.6 | 19 | 2.3 | | .4 | 29 | 2.5 | 2.5 | .7 |
| 9 | 1.8 | 2.5 | 2.6 | 20 | 2.3 | 2.1 | .4 | 30 | 2.5 | 2.5 | |
| 10 | 2.0 | 2.5 | 2.6 | 21 | 2.4 | 2.2 | .3 | 31 | 2.5 | 2.5 | |
| 11 | 2.0 | 2.5 | 2.5 | | | | | | | | |

### TOWN CANAL NEAR ELLENSBURG, WASH.

This canal heads in the left bank of Yakima River about 9 miles northwest of Ellensburg, in sec. 7, T. 18 N., R. 18 E.

The gage is about one-fourth mile below the head-gates of the canal, and is attached to a cattle bridge, from which measurements are made.

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*Discharge measurements of Town canal near Ellensburg, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 13 | W. C. Muldrow | 62 | 2.13 | 3.58 | 132 |
| August 30 | do | 57 | 2.15 | 3.70 | 122 |
| October 6 | do | 42 | 2.07 | 2.90 | 86 |

*Daily gage height, in feet, of Town canal near Ellensburg, Wash., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Day. | July. | Aug. | Sept. | Oct. | Day. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 3.7 | 3.85 | 3.4 | 12 | 3.65 | 3.5 | 3.65 | 2.25 | 22 | 3.9 | 3.85 | 3.5 | ..... |
| 2 | ..... | 3.65 | 3.35 | 3.4 | 13 | 3.6 | 3.6 | 3.65 | 2.25 | 23 | 3.9 | 3.85 | 3.6 | ..... |
| 3 | ..... | 3.7 | 3.85 | 3.35 | 14 | 3.6 | 3.6 | 3.65 | ..... | 24 | 3.9 | 3.85 | 3.6 | ..... |
| 4 | ..... | 3.7 | 3.75 | 3.4 | 15 | 3.65 | 3.65 | 3.6 | ..... | 25 | 3.85 | 3.85 | 3.6 | ..... |
| 5 | ..... | 3.65 | 3.75 | 3.1 | 16 | 3.75 | 3.8 | 3.55 | ..... | 26 | 3.85 | 3.85 | 3.6 | ..... |
| 6 | 3.75 | 3.65 | 3.75 | 2.15 | 17 | 3.75 | 3.85 | 3.5 | ..... | 27 | 3.85 | 3.9 | 3.6 | ..... |
| 7 | 3.75 | 3.6 | 3.85 | 2.15 | 18 | 3.85 | 3.9 | 3.5 | ..... | 28 | 3.8 | 3.9 | 3.75 | ..... |
| 8 | 3.8 | 3.6 | 3.8 | 2.2 | 19 | 3.85 | 3.9 | 3.5 | ..... | 29 | 3.75 | 3.85 | 3.4 | ..... |
| 9 | 3.8 | 3.6 | 3.8 | 2.2 | 20 | 3.9 | 3.9 | 3.5 | ..... | 30 | 3.75 | 3.85 | 3.4 | ..... |
| 10 | 3.75 | 3.6 | 3.7 | 2.2 | 21 | 3.9 | 3.9 | 3.5 | ..... | 31 | 3.7 | 3.85 | ..... | ..... |
| 11 | 3.65 | 3.5 | 3.65 | 2.25 | | | | | | | | | | |

### OLSEN CANAL NEAR ELLENSBURG, WASH.

This canal heads in the left bank of Yakima River just below the Town canal.

The gage is attached to a wagon bridge near Charles Kuli's house. Measurements are made from a foot log a short distance above the gage.

*Discharge measurements of Olsen canal near Ellensburg, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 13 | W. C. Muldrow | 12.0 | 1.17 | 1.95 | 14.0 |
| August 30 | do | 14.7 | 1.56 | 2.20 | 23.0 |
| September 21 | do | 14.1 | 1.43 | 2.15 | 20.1 |
| October 6 | do | 18.6 | .50 | 2.00 | 9.3 |

*Daily gage height, in feet, of Olsen canal near Ellensburg, Wash., for 1905.*

| Day. | Sept. | Oct. | Day. | Sept. | Oct. | Day. | Sept. | Oct. | Day. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 2.05 | 9 | 1.95 | 2.3 | 17 | 2.3 | ..... | 24 | 2.2 | ..... |
| 2 | ..... | 1.95 | 10 | 1.9 | 2.3 | 18 | 2.3 | ..... | 25 | 2.2 | ..... |
| 3 | ..... | 1.95 | 11 | 1.95 | 2.4 | 19 | 2.25 | ..... | 26 | 2.2 | ..... |
| 4 | 1.9 | 1.95 | 12 | 2.3 | ..... | 20 | 2.2 | ..... | 27 | 2.2 | ..... |
| 5 | 1.9 | 1.95 | 13 | 2.3 | ..... | 21 | 2.2 | ..... | 28 | 2.2 | ..... |
| 6 | 1.9 | 2.0 | 14 | 2.3 | ..... | 22 | 2.2 | ..... | 29 | 2.2 | ..... |
| 7 | 1.95 | 2.0 | 15 | 2.25 | ..... | 23 | 2.2 | ..... | 30 | 2.05 | ..... |
| 8 | 1.95 | 2.3 | 16 | 2.25 | ..... | | | | | | |

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### SELAH-MOXEE CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the left bank of Yakima River just below Yakima Canyon, in sec. 8, T. 14 N., R. 19 E. It is the next important canal below the Olsen canal.

The gage is at a footbridge near Selah siding, 1½ miles below the head-gates. Measurements are made from the footbridge.

*Discharge measurements of Selah-Moxee canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 5 | W. C. Muldrow | 3.10 | 1.74 | 2.3 | 54.0 |
| August 11 | do | 41.6 | 1.64 | 2.77 | 68.0 |
| September 9 | do | 40.5 | 1.50 | 2.70 | 60.7 |
| September 30 | do | ..... | ..... | 2.75 | 61.8 |
| October 12 | do | 20.0 | 1.00 | 1.65 | 20.0 |

*Daily gage height, in feet, of Selah-Moxee canal near North Yakima, Wash., for 1905.*

| Day. | July. | Aug. | Sept. | Day. | July. | Aug. | Sept. | Day. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 3.0 | 2.8 | 12 | 2.8 | 2.8 | 2.8 | 22 | 2.8 | 2.9 | 2.4 |
| 2 | ..... | 2.9 | 2.9 | 13 | 2.8 | 2.8 | 2.7 | 23 | 2.8 | 2.9 | 2.3 |
| 3 | ..... | 3.0 | 2.8 | 14 | 2.7 | 2.8 | 2.6 | 24 | 2.8 | 3.0 | 2.2 |
| 4 | ..... | 3.0 | 2.8 | 15 | 2.8 | 2.8 | 2.4 | 25 | 2.8 | 3.0 | 2.2 |
| 5 | 2.3 | 2.9 | 2.8 | 16 | 2.7 | 2.8 | 2.4 | 26 | 2.9 | 3.0 | 2.3 |
| 6 | 2.3 | 2.9 | 2.8 | 17 | 2.7 | 2.8 | 2.4 | 27 | 2.9 | 3.0 | 2.3 |
| 7 | 2.4 | 2.9 | 2.8 | 18 | 2.7 | 2.8 | 2.4 | 28 | 2.9 | 3.0 | 2.3 |
| 8 | 2.5 | 2.8 | 2.8 | 19 | 2.7 | 3.0 | 2.4 | 29 | 3.0 | 3.0 | 2.3 |
| 9 | 2.6 | 2.8 | 2.7 | 20 | 2.7 | 2.9 | 2.4 | 30 | 3.0 | 2.8 | 2.4 |
| 10 | 2.8 | 2.9 | 2.7 | 21 | 2.7 | 3.0 | 2.4 | 31 | 3.0 | 2.8 | ..... |
| 11 | 2.8 | 2.8 | 2.7 | | | | | | | | |

### TAYLOR CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the right bank of Yakima River about 4 miles above the mouth of Naches River.

The gage is about 100 feet above the dividing gates. Measurements are made from a foot plank 50 feet below the gage.

*Discharge measurements of Taylor canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 5 | W. C. Muldrow | 12.0 | 1.25 | ..... | 15.0 |
| August 18 | do | 12.0 | 1.23 | 0.95 | 14.6 |
| September 9 | do | 13.6 | 1.38 | 1.10 | 18.7 |
| October 12 | do | 5.0 | .36 | .30 | 1.8 |



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*Daily gage height, in feet, of Taylor canal near North Yakima, Wash., for 1905.*

| Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.05 | 0.55 | 12 | ..... | 1.1 | 0.3 | 22 | 1.0 | 1.1 | ..... |
| 2 | ..... | 1.05 | .55 | 13 | ..... | 1.15 | .25 | 23 | 1.0 | 1.1 | ..... |
| 3 | ..... | 1.05 | .55 | 14 | ..... | 1.15 | .3 | 24 | 1.1 | .65 | ..... |
| 4 | ..... | 1.05 | .5 | 15 | ..... | 1.1 | ..... | 25 | 1.05 | .65 | ..... |
| 5 | ..... | 1.05 | .5 | 16 | ..... | 1.1 | ..... | 26 | 1.05 | .6 | ..... |
| 6 | ..... | 1.0 | .5 | 17 | ..... | 1.1 | ..... | 27 | 1.05 | .6 | ..... |
| 7 | ..... | 1.05 | .5 | 18 | ..... | 0.95 | 1.15 | ..... | 28 | 1.05 | .6 | ..... |
| 8 | ..... | 1.1 | .45 | 19 | ..... | .95 | 1.15 | ..... | 29 | 1.1 | .55 | ..... |
| 9 | ..... | 1.2 | .3 | 20 | ..... | .9 | 1.15 | ..... | 30 | 1.1 | .55 | ..... |
| 10 | ..... | 1.15 | .3 | 21 | ..... | 1.0 | 1.1 | ..... | 31 | 1.05 | ..... | ..... |
| 11 | ..... | 1.1 | .3 | | | | | | | | |

## MOXEE CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the left bank of Yakima River near the line between secs. 7 and 18, T. 13 N., R. 19 E., opposite the town of North Yakima.

The gage is one-half mile below the head-gates on the Moxee hop ranch, about 300 feet above the foot plank from which measurements are made.

*Discharge measurements of Moxee canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 6 | W. C. Muldrow | 7.1 | 1.07 | 0.50 | 7.6 |
| August 21 | do | 17.0 | .99 | 1.05 | 16.8 |
| August 21 | do | 13.4 | 1.00 | 1.05 | 13.4 |
| September 26 | do | 9.3 | .81 | .80 | 7.6 |
| October 13 | do | 5.3 | .45 | .16 | 2.3 |

*Daily gage height, in feet, of Moxee canal near North Yakima, Wash., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Day. | July. | Aug. | Sept. | Oct. | Day. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.25 | 1.1 | 0.75 | 12 | 1.1 | 1.0 | 0.9 | .15 | 22 | 1.0 | 1.15 | 0.65 | ..... |
| 2 | ..... | 1.15 | 1.0 | .75 | 13 | 1.15 | 1.0 | .9 | .15 | 23 | 1.25 | 1.15 | .65 | ..... |
| 3 | ..... | 1.15 | 1.0 | .75 | 14 | 1.15 | .9 | .9 | .15 | 24 | 1.25 | 1.35 | .65 | ..... |
| 4 | ..... | 1.15 | 1.0 | .75 | 15 | 1.15 | 1.0 | 1.0 | .15 | 25 | 1.15 | 1.25 | .65 | ..... |
| 5 | ..... | .85 | 1.15 | .75 | 16 | 1.1 | .9 | .9 | .15 | 26 | 1.15 | 1.15 | .65 | ..... |
| 6 | 0.5 | .65 | 1.15 | .75 | 17 | 1.1 | .9 | .75 | .15 | 27 | 1.4 | 1.15 | .65 | ..... |
| 7 | .5 | .5 | 1.15 | .15 | 18 | 1.1 | .9 | .75 | .15 | 28 | 1.4 | 1.25 | .75 | ..... |
| 8 | .85 | .5 | 1.15 | .15 | 19 | 1.0 | 1.1 | .75 | .15 | 29 | 1.35 | 1.35 | .75 | ..... |
| 9 | .85 | .5 | 1.0 | .15 | 20 | 1.0 | 1.1 | .65 | .15 | 30 | 1.25 | 1.35 | .75 | ..... |
| 10 | 1.15 | 1.0 | 1.0 | .15 | 21 | 1.0 | 1.0 | .65 | .15 | 31 | 1.25 | 1.15 | ..... | ..... |
| 11 | .4 | 1.0 | .9 | .15 | | | | | | | | | | |

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### HUBBARD CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the left bank of Yakima River near the line between secs. 7 and 18, T. 13 N., R. 19 E., opposite the town of North Yakima.

The gage is about one-half mile below the head-gates, at a small flume near the hop house on the Moxee hop ranch. Measurements are made from a wagon bridge 300 feet below the gage.

The Hubbard and Moxee canals have a common head-gate.

*Discharge measurements of Hubbard canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 6 | W. C. Muldrow | 20.0 | 0.72 | 1.33 | 14.3 |
| August 21 | do | 13.1 | 1.61 | 1.50 | 21.1 |
| September 26 | do | 9.8 | 1.02 | 1.20 | 10.2 |
| October 13 | do | 8.6 | .60 | .92 | 5.1 |

*Daily gage height, in feet, of Hubbard canal near North Yakima, Wash., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Day. | July. | Aug. | Sept. | Oct. | Day. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.75 | 1.5 | 1.4 | 12 | 1.75 | 1.15 | 1.4 | 1.0 | 22 | 1.35 | 1.5 | 1.4 | ..... |
| 2 | ..... | 1.75 | 1.5 | 1.4 | 13 | 1.75 | 1.15 | 1.4 | 1.0 | 23 | 1.4 | 1.35 | 1.4 | ..... |
| 3 | ..... | 1.65 | 1.5 | 1.4 | 14 | 1.75 | 1.15 | 1.4 | 1.0 | 24 | 1.5 | 1.4 | 1.25 | ..... |
| 4 | ..... | 1.65 | 1.5 | 1.5 | 15 | 1.75 | 1.35 | 1.4 | 1.0 | 25 | 1.6 | 1.4 | 1.25 | ..... |
| 5 | ..... | 1.65 | 1.5 | 1.5 | 16 | 1.65 | 1.35 | 1.4 | 1.0 | 26 | 1.6 | 1.35 | 1.25 | ..... |
| 6 | 1.35 | 1.65 | 1.4 | 1.5 | 17 | 1.65 | 1.25 | 1.4 | 1.0 | 27 | 1.85 | 1.25 | 1.25 | ..... |
| 7 | 1.35 | 1.65 | 1.5 | 1.0 | 18 | 1.5 | 1.25 | 1.4 | 1.0 | 28 | 1.75 | 1.35 | 1.25 | ..... |
| 8 | 1.5 | 1.5 | 1.5 | 1.0 | 19 | 1.5 | 1.4 | 1.4 | 1.0 | 29 | 1.75 | 1.4 | 1.25 | ..... |
| 9 | 1.5 | 1.5 | 1.4 | 1.0 | 20 | 1.35 | 1.4 | 1.35 | 1.0 | 30 | 1.75 | 1.6 | 1.4 | ..... |
| 10 | 1.9 | 1.4 | 1.4 | 1.0 | 21 | 1.35 | 1.6 | 1.35 | 1.0 | 31 | 1.75 | 1.4 | ..... | ..... |
| 11 | 1.85 | 1.35 | 1.4 | 1.0 | | | | | | | | | | |

### FOWLER CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in Yakima River, in sec. 18, T. 13 N., R. 19 E.

The gage is in a flume one-half mile below the head-gates, on the Moxie hop ranch, opposite the town of North Yakima. Measurements are made at the gage.

*Discharge measurements of Fowler canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 6 | W. C. Muldrow | 9.7 | 2.02 | 0.75 | 19.6 |
| August 21 | do | 11.7 | 2.04 | .92 | 23.9 |
| September 26 | do | 9.0 | 1.48 | .55 | 13.4 |

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*Daily gage height, in feet, of Fowler canal near North Yakima, Wash., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Day. | July. | Aug. | Sept. | Oct. | Day. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 0.9 | 0.85 | 0.6 | 12 | .85 | .85 | .65 | ..... | 22 | .9 | .9 | .5 | ..... |
| 2 | ..... | .9 | .85 | .6 | 13 | .85 | .85 | .65 | ..... | 23 | .85 | .9 | .5 | ..... |
| 3 | ..... | .9 | .85 | .6 | 14 | .9 | .85 | .65 | ..... | 24 | .9 | .9 | .65 | ..... |
| 4 | ..... | .85 | .85 | ..... | 15 | .9 | .85 | .65 | ..... | 25 | .9 | .9 | .6 | ..... |
| 5 | ..... | .85 | .85 | ..... | 16 | .9 | .85 | .5 | ..... | 26 | .9 | .9 | .6 | ..... |
| 6 | 0.75 | .85 | .75 | ..... | 17 | .9 | .85 | .5 | ..... | 27 | .9 | .85 | .6 | ..... |
| 7 | .75 | .85 | .65 | ..... | 18 | .9 | .85 | .5 | ..... | 28 | .9 | .85 | .6 | ..... |
| 8 | .75 | .85 | .65 | ..... | 19 | .9 | .9 | .5 | ..... | 29 | .9 | .85 | .6 | ..... |
| 9 | .65 | .85 | .65 | ..... | 20 | .9 | .9 | .5 | ..... | 30 | .9 | .85 | .6 | ..... |
| 10 | .85 | .85 | .65 | ..... | 21 | .9 | .9 | .5 | ..... | 31 | .9 | .85 | ..... | ..... |
| 11 | .9 | .85 | .65 | ..... | | | | | | | | | | |

## NEW RESERVATION CANAL IN YAKIMA INDIAN RESERVATION, WASH.

This is the first canal taking water from Yakima River below Atanum Creek. It was built by the Government to irrigate lands in the Yakima Indian Reservation. It heads in the right bank in sec. 17, T. 12 N., R. 19 E.

The gage is at the first wagon bridge below the headworks. Measurements are made from the bridge.

*Discharge measurements of New Reservation canal in Yakima Indian Reservation, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 16 | W. C. Muldrow | 60 | 1.80 | 1.50 | 108 |
| August 22 | do | 112 | 1.25 | 2.58 | 140 |
| September 20 | do | ..... | ..... | 1.97 | 62 |
| September 27 | do | 79 | .69 | 1.83 | 55 |
| October 24 | do | 50 | .82 | 1.04 | 41 |

*Daily gage height, in feet, of New Reservation canal in Yakima Indian Reservation, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1.6 | 2.25 | 1.6 | 12 | 1.5 | 2.15 | 2.55 | ..... | 22 | 1.65 | 2.1 | 2.6 | ..... |
| 2 | 1.5 | 1.6 | 2.3 | 1.65 | 13 | 1.5 | 2.15 | 2.5 | ..... | 23 | 1.65 | 2.1 | 2.6 | ..... |
| 3 | 1.5 | 1.65 | 2.45 | ..... | 14 | 1.5 | 2.2 | 2.5 | ..... | 24 | 1.65 | 2.15 | 2.6 | ..... |
| 4 | 1.15 | 1.75 | 2.6 | ..... | 15 | 1.5 | 2.2 | 2.5 | ..... | 25 | 1.35 | 2.15 | 2.6 | ..... |
| 5 | 1.0 | 1.75 | 2.7 | ..... | 16 | 1.6 | 2.25 | 2.55 | ..... | 26 | 1.35 | 2.15 | 2.0 | ..... |
| 6 | 1.0 | 1.9 | 2.7 | ..... | 17 | 1.6 | 2.2 | 2.6 | ..... | 27 | 1.35 | 2.2 | 2.0 | ..... |
| 7 | 1.1 | 2.0 | 2.7 | ..... | 18 | 1.65 | 2.15 | 2.65 | ..... | 28 | .85 | 2.25 | 1.75 | ..... |
| 8 | 1.15 | 2.25 | 2.65 | ..... | 19 | 1.65 | 2.15 | 3.0 | ..... | 29 | 1.35 | 2.25 | 1.65 | ..... |
| 9 | 1.35 | 2.05 | 2.65 | ..... | 20 | 1.65 | 2.1 | 2.65 | ..... | 30 | 1.45 | 2.25 | 1.6 | ..... |
| 10 | 1.4 | 2.1 | 2.65 | ..... | 21 | 1.65 | 2.1 | 2.65 | ..... | 31 | ..... | 2.25 | 1.7 | ..... |
| 11 | 1.4 | 2.15 | 2.6 | ..... | | | | | | | | | | |

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### OLD RESERVATION CANAL IN YAKIMA INDIAN RESERVATION, WASH.

This canal takes water from Yakima River, heading in its right bank, in sec. 28, T. 12 N., R. 19 E., about 4 miles above Wapato station. It was built by the Government to irrigate lands in the Yakima Indian Reservation.

The gage is at the head-gate. Measurements are made from the railway bridge one-fourth mile below the gage.

*Discharge measurements of Old Reservation canal in Yakima Indian Reservation, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 16 | W. C. Muldrow | 37.4 | 3.85 | 2.67 | 144 |
| August 22 | do | 26.4 | 3.07 | 2.08 | 81.4 |
| October 24 | do | 17.6 | 2.01 | 1.40 | 35.4 |

*Daily gage height, in feet, of Old Reservation canal in Yakima Indian Reservation, Wash., for 1905.*

| Day. | May. | June. | July. | Aug. | Day. | May. | June. | July. | Aug. | Day. | May. | June. | July. | Aug. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.35 | 3.4 | 3.35 | 3.1 | 12 | 3.35 | 2.6 | 3.35 | 2.65 | 22 | 3.35 | 3.35 | 3.25 | 2.25 |
| 2 | 3.35 | 3.5 | 3.25 | 3.1 | 13 | 3.25 | 2.65 | 3.25 | 2.6 | 23 | 3.25 | 3.35 | 3.25 | 2.25 |
| 3 | 3.35 | 3.35 | 3.35 | 3.1 | 14 | 3.25 | 2.65 | 3.15 | 2.5 | 24 | 3.35 | 3.35 | 3.15 | 2.25 |
| 4 | 3.35 | 2.65 | 3.25 | 3.1 | 15 | 3.25 | 2.6 | 3.15 | 2.35 | 25 | 3.35 | 3.25 | 3.15 | 2.25 |
| 5 | 3.35 | 2.65 | 3.35 | 3.0 | 16 | 3.25 | 2.65 | 3.15 | 2.25 | 26 | 3.35 | 3.35 | 3.1 | 2.15 |
| 6 | 3.4 | 2.65 | 3.35 | 3.0 | 17 | 3.25 | 3.1 | 3.15 | 2.25 | 27 | 3.25 | 3.25 | 3.0 | 2.15 |
| 7 | 3.5 | 2.65 | 3.25 | 3.0 | 18 | 3.35 | 3.15 | 3.15 | 2.41 | 28 | 3.25 | 3.35 | 3.15 | 2.15 |
| 8 | 3.6 | 2.6 | 3.35 | 3.0 | 19 | 3.35 | 3.25 | 3.15 | 2.25 | 29 | 3.35 | 3.35 | 3.15 | 2.15 |
| 9 | 3.6 | 2.6 | 3.5 | 2.9 | 20 | 3.35 | 3.25 | 3.1 | 2.25 | 30 | 3.4 | 3.25 | 3.2 | 2.25 |
| 10 | 3.35 | 2.65 | 3.4 | 2.85 | 21 | 3.35 | 3.25 | 3.0 | 2.25 | 31 | 3.35 | ..... | 3.1 | 2.25 |
| 11 | 3.25 | 2.6 | 3.4 | 2.75 | | | | | | | | | | |

### SUNNYSIDE CANAL NEAR YAKIMA, WASH.

This canal, which is owned and operated by the Washington Irrigation Company, heads in the east bank of Yakima River, 5 miles below the town of Yakima. It is several times larger than any other canal in the Yakima region, the maximum flow being about 670 second-feet.

The gage is in a concrete gage box about 400 feet below the head-gates. Measurements are made from a footbridge about 400 feet below the gage.

*Discharge measurements of Sunnyside canal near Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 15 | W. C. Muldrow | 175 | 3.00 | 4.35 | 526 |
| July 25 | do | 210 | 3.09 | 5.06 | 649 |
| September 28 | do | 162 | 2.90 | 4.00 | 469 |
| October 25 | do | 128 | 2.35 | 3.35 | 301 |
| November 5 | do | 68.8 | 2.01 | 2.00 | 139 |

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*Daily gage height, in feet, of Sunnyside canal near Yakima, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Day. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 4.7 | 5.15 | 4.75 | 3.95 | 17 | 4.2 | 5.1 | 4.6 | 4.05 | 3.4 |
| 2 | ..... | 4.7 | 5.15 | 4.75 | 3.95 | 18 | 4.4 | 5.1 | 4.6 | 3.95 | 3.4 |
| 3 | ..... | 4.7 | 5.15 | 4.65 | 3.95 | 19 | 4.5 | 5.1 | 4.9 | 3.95 | 3.4 |
| 4 | ..... | 4.7 | 5.15 | 4.65 | 3.8 | 20 | 4.5 | 5.1 | 5.1 | 3.95 | 3.4 |
| 5 | ..... | 4.7 | 5.15 | 4.65 | 3.7 | 21 | 4.5 | 0.0 | 5.15 | 3.95 | 3.5 |
| 6 | ..... | 4.8 | 5.15 | 4.55 | 3.7 | 22 | 4.6 | 5.1 | 5.0 | 3.95 | 3.5 |
| 7 | ..... | 4.9 | 5.15 | 4.55 | 3.7 | 23 | 4.6 | 0.0 | 4.65 | 3.95 | 3.3 |
| 8 | ..... | 4.9 | 5.15 | 4.55 | 3.4 | 24 | 4.7 | 5.1 | 4.6 | 3.95 | 3.3 |
| 9 | ..... | 5.0 | 5.15 | 4.55 | 3.4 | 25 | 4.7 | 5.1 | 4.8 | 3.95 | 3.3 |
| 10 | ..... | 5.0 | 5.15 | 4.55 | 3.4 | 26 | 4.7 | 5.1 | 4.8 | 3.95 | 3.3 |
| 11 | ..... | 5.0 | 4.9 | 4.55 | 3.4 | 27 | 4.7 | 5.15 | 4.8 | 3.95 | 3.3 |
| 12 | ..... | 5.0 | 4.9 | 4.55 | 3.4 | 28 | 4.7 | 5.15 | 4.8 | 3.95 | 3.3 |
| 13 | ..... | 5.0 | 4.8 | 4.4 | 3.4 | 29 | 4.7 | 5.15 | 4.8 | 3.95 | 3.3 |
| 14 | ..... | 5.1 | 4.75 | 4.4 | 3.4 | 30 | 4.7 | 5.15 | 4.75 | 3.95 | 3.3 |
| 15 | 4.2 | 5.1 | 4.6 | 4.4 | 3.4 | 31 | ..... | 5.15 | 4.75 | ..... | 3.3 |
| 16 | 4.2 | 5.1 | 4.6 | 4.15 | 3.4 | | | | | | |

### BENTON WATER COMPANY'S CANAL NEAR KIONA, WASH.

This canal takes water from Yakima River near Kiona. It is a new canal, completed late in the irrigation season of 1905.

*Discharge measurements of Benton Water Company's canal near Kiona, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 23 | W. C. Muldrow | 8.0 | 0.86 | 0.30 | 6.9 |
| September 13 | do | 16.1 | 1.23 | .60 | 19.8 |

*Daily gage height, in feet, of Benton Water Company's canal near Kiona, Wash., for 1905.*

| Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 0.1 | 1.0 | 12 | ..... | 0.55 | 0.3 | 22 | ..... | 0.9 | ..... |
| 2 | ..... | .15 | 1.0 | 13 | ..... | .55 | .3 | 23 | 0.3 | .9 | ..... |
| 3 | ..... | .3 | 1.0 | 14 | ..... | .6 | .3 | 24 | .3 | .9 | ..... |
| 4 | ..... | .3 | 1.0 | 15 | ..... | .6 | .3 | 25 | .2 | .9 | ..... |
| 5 | ..... | .4 | .4 | 16 | ..... | .7 | .3 | 26 | .2 | .9 | ..... |
| 6 | ..... | .5 | .4 | 17 | ..... | .7 | .3 | 27 | .2 | .9 | ..... |
| 7 | ..... | .5 | .4 | 18 | ..... | .7 | .3 | 28 | .2 | .9 | ..... |
| 8 | ..... | .5 | .4 | 19 | ..... | .8 | ..... | 29 | .1 | 1.0 | ..... |
| 9 | ..... | .6 | .4 | 20 | ..... | .8 | ..... | 30 | .1 | 1.0 | ..... |
| 10 | ..... | .6 | .3 | 21 | ..... | .8 | ..... | 31 | .1 | ..... | ..... |
| 11 | ..... | .6 | .3 | | | | | | | | |

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### KIONA CANAL NEAR KIONA, WASH.

This canal heads in the left bank of Yakima River about 5 miles west of Kiona, in sec. 10, T. 9 N., R. 26 E. The canal is controlled by the Northern Pacific Irrigation Company. On account of the shifting of the channel at the gaging station the estimates of discharge of this canal are only approximate.

The gage is about 400 feet below the head-gates. Measurements are made from a foot plank near the gage.

*Discharge measurements of Kiona canal near Kiona, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 12 | W. C. Muldrow | 20.4 | 1.17 | 3.00 | 23.9 |
| August 24 | do | 19.0 | 1.26 | 3.00 | 23.9 |
| August 24 | do | 6.8 | .50 | 2.00 | 3.4 |

*Daily gage height, in feet, of Kiona canal near Kiona, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Day. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | ..... | 3.25 | 3.1 | 3.0 | 17 | 3.15 | 3.25 | 3.45 | 3.0 | ..... |
| 2 | ..... | ..... | 3.3 | 3.1 | 3.0 | 18 | 3.15 | 3.15 | 3.45 | 3.0 | ..... |
| 3 | ..... | ..... | 3.3 | 3.1 | 2.5 | 19 | 3.25 | 3.1 | 3.4 | 3.0 | ..... |
| 4 | ..... | ..... | 3.3 | 3.1 | 2.5 | 20 | 3.25 | 3.0 | 3.35 | 3.0 | ..... |
| 5 | ..... | ..... | 3.3 | 3.1 | 2.5 | 21 | 3.4 | 3.0 | 3.35 | 3.0 | ..... |
| 6 | ..... | ..... | 3.35 | 3.1 | 2.5 | 22 | 3.4 | 3.0 | 3.1 | 3.0 | ..... |
| 7 | ..... | ..... | 3.35 | 3.1 | 2.5 | 23 | 3.4 | 3.0 | 3.1 | 3.0 | ..... |
| 8 | ..... | 2.9 | 3.25 | 3.1 | 2.5 | 24 | 3.6 | 3.0 | 3.0 | 3.0 | ..... |
| 9 | ..... | 2.9 | 3.3 | 3.1 | 2.5 | 25 | ..... | 3.0 | 3.0 | 3.0 | ..... |
| 10 | ..... | 3.15 | 3.4 | 3.1 | 2.5 | 26 | ..... | 2.9 | 3.0 | 3.0 | ..... |
| 11 | ..... | 3.25 | 3.55 | 3.1 | 2.5 | 27 | ..... | 2.9 | 3.1 | 3.0 | ..... |
| 12 | 3.0 | 3.25 | 3.5 | 3.1 | 2.5 | 28 | ..... | 2.85 | 3.1 | 3.0 | ..... |
| 13 | 3.1 | 3.35 | 3.5 | 3.1 | 2.7 | 29 | ..... | 2.9 | 3.1 | 3.0 | ..... |
| 14 | 3.1 | 3.35 | 3.5 | 3.1 | 2.5 | 30 | ..... | 3.0 | 3.1 | 3.0 | ..... |
| 15 | 3.1 | 3.25 | 3.5 | 3.1 | 2.5 | 31 | ..... | 3.15 | 3.1 | ..... | ..... |
| 16 | 3.15 | 3.25 | 3.5 | 3.1 | ..... | | | | | | |

### KIONA WATER SUPPLY COMPANY'S CANAL NEAR KIONA, WASH.

This canal heads in the left bank of Yakima River about 1 mile above Kiona. It is owned by a stock company of 150 shares. It is a power canal used to turn small irrigating wheels. Nearly all the water taken in at the head is returned to the river.

The gage is 200 feet below the footbridge from which measurements are made, near the dwelling of A. A. McAlpin.

*Discharge measurements of Kiona Water Supply Company's canal near Kiona, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| September 14 | W. C. Muldrow | 7.8 | 0.96 | 1.50 | 7.5 |
| October 18 | do | 9.3 | 1.07 | 1.90 | 10.0 |

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*Daily gage height, in feet, of Kiona Water Supply Company's canal near Kiona, Wash., for 1905.*

| Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 1.2 | 1.8 | 12 | | 1.3 | 2.0 | 22 | | 1.8 | |
| 2 | | 1.2 | 1.8 | 13 | | 1.3 | 2.0 | 23 | | 1.8 | |
| 3 | | 1.1 | 1.9 | 14 | | 1.5 | 2.0 | 24 | | 1.8 | |
| 4 | | 1.1 | 2.0 | 15 | | 1.6 | | 25 | | 1.8 | |
| 5 | | 1.1 | 2.0 | 16 | | 1.7 | | 26 | | 1.8 | |
| 6 | | 1.2 | 2.0 | 17 | | 1.7 | | 27 | 0.7 | 1.8 | |
| 7 | | 1.2 | 2.0 | 18 | | 1.7 | | 28 | .9 | 1.8 | |
| 8 | | 1.3 | 2.0 | 19 | | 1.7 | | 29 | 1.0 | 1.8 | |
| 9 | | 1.3 | 2.0 | 20 | | 1.7 | | 30 | 1.0 | 1.8 | |
| 10 | | 1.3 | 2.0 | 21 | | 1.7 | | 31 | 1.1 | | |
| 11 | | 1.3 | 2.0 | | | | | | | | |

## KENNEWICK CANAL NEAR KENNEWICK, WASH.

This canal is owned and operated by the Northern Pacific Irrigation Company. Next to the Sunnyside it is the largest irrigation canal in Yakima Valley. It takes water from Yakima River on its right bank just above Horn Rapids, about 11 miles north of Kiona, in sec. 3, T. 10 N., R. 27 E.

The gage is at a bridge 1¼ miles below the head-gates. Measurements are made from the bridge.

*Discharge measurements of Kennewick canal near Kennewick, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 10 | W. C. Muldrow | 68 | 1.5 | 2.83 | 102 |
| August 23 | do | 76 | 2.14 | 3.42 | 162 |
| September 14 | do | 83 | 2.10 | 3.47 | 174 |

*Daily gage height, in feet, of Kennewick canal near Kennewick, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Day. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 3.35 | 3.5 | 3.25 | 3.25 | 17 | 3.35 | 3.4 | 2.9 | 3.5 | 3.1 |
| 2 | | 3.35 | 3.5 | 3.15 | 3.25 | 18 | 3.4 | 3.4 | 3.0 | 3.5 | 3.1 |
| 3 | | 3.35 | | 3.25 | 3.25 | 19 | 1.75 | 3.4 | 3.15 | 3.4 | 3.1 |
| 4 | | 3.4 | 2.5 | 3.35 | 3.15 | 20 | 1.75 | 3.4 | 3.15 | 3.35 | 3.1 |
| 5 | | 3.4 | | 3.35 | 3.25 | 21 | 2.9 | 3.5 | 3.25 | 3.35 | 1.0 |
| 6 | | 3.4 | 2.5 | 3.4 | 3.25 | 22 | 3.35 | 3.5 | 3.35 | 3.35 | 2.15 |
| 7 | | 3.4 | 2.75 | 3.4 | 3.15 | 23 | 3.4 | 3.5 | 3.4 | 3.35 | 2.85 |
| 8 | | 3.8 | 2.0 | 3.35 | 3.0 | 24 | 3.4 | 3.5 | 3.35 | 3.35 | 2.85 |
| 9 | | 3.4 | 2.0 | 3.25 | 3.0 | 25 | 3.4 | 3.5 | 3.25 | 3.35 | 2.85 |
| 10 | 2.85 | 3.4 | 2.0 | 3.5 | 3.0 | 26 | 3.35 | 3.5 | 3.25 | 3.35 | 2.85 |
| 11 | 2.85 | 3.4 | 2.4 | 3.35 | 2.95 | 27 | 3.35 | 3.5 | 3.25 | 3.35 | 2.85 |
| 12 | 2.85 | 3.4 | 2.6 | 3.4 | 2.75 | 28 | 3.35 | 3.5 | 3.15 | 3.25 | 2.85 |
| 13 | 2.85 | 3.4 | 3.15 | 3.4 | 3.1 | 29 | 3.35 | 3.5 | 3.35 | 3.35 | 2.85 |
| 14 | 3.25 | 3.4 | 3.1 | 3.4 | 3.1 | 30 | 3.35 | 3.5 | 3.35 | 3.25 | 1.15 |
| 15 | 3.25 | 3.4 | 3.0 | 3.4 | 3.1 | 31 | | 3.5 | 3.25 | | 1.15 |
| 16 | 3.35 | 3.4 | 2.9 | 3.5 | 3.1 | | | | | | |

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### GROSSCUP CANAL NEAR KIONA, WASH.

This canal heads in Yakima River on its left bank at Horn Rapids, directly opposite the intake of the Kennewick canal. The same diversion weir is used for both canals.

The gage is 1 mile below the head-gates, at a highway bridge, from which measurements are made.

*Discharge measurements of Grosscup canal near Kiona, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 13 | W. C. Muldrow | 2.9 | 1.55 | 0.50 | 4.5 |
| August 23 | do | 3.3 | 1.66 | .60 | 5.5 |
| September 13 | do | 3.4 | 1.94 | .70 | 6.6 |

*Daily gage height, in feet, of Grosscup canal near Kiona, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 0.6 | 1.0 | 0.8 | 12 | 0.6 | .8 | .8 | .8 | 22 | .7 | 1.0 | .8 | .8 |
| 2 | ..... | .6 | 1.0 | .8 | 13 | .6 | .8 | .8 | .8 | 23 | .7 | 1.0 | .8 | .8 |
| 3 | ..... | .6 | 1.0 | .8 | 14 | .7 | .9 | .7 | .8 | 24 | .7 | 1.0 | .8 | .8 |
| 4 | ..... | .6 | 1.0 | .8 | 15 | .7 | 1.0 | .8 | .8 | 25 | .7 | 1.0 | .8 | .8 |
| 5 | ..... | .6 | 1.0 | .8 | 16 | .7 | 1.0 | .8 | .8 | 26 | .7 | 1.0 | .8 | .8 |
| 6 | ..... | .6 | 0.0 | .8 | 17 | .6 | 1.0 | .8 | .8 | 27 | .7 | 1.0 | .8 | .8 |
| 7 | ..... | .6 | 0.0 | .8 | 18 | .6 | 1.0 | .8 | .8 | 28 | .7 | 1.0 | .8 | .8 |
| 8 | ..... | .6 | .8 | .8 | 19 | .7 | 1.0 | .8 | .8 | 29 | .7 | 1.0 | .8 | .8 |
| 9 | ..... | .6 | .8 | .8 | 20 | .7 | 1.0 | .8 | .8 | 30 | .7 | 1.0 | .8 | .8 |
| 10 | ..... | .6 | .8 | .8 | 21 | .7 | 1.0 | .8 | .8 | 31 | ..... | 1.0 | .8 | ..... |
| 11 | ..... | .7 | .8 | .8 | | | | | | | | | | |

### SELAH VALLEY CANAL NEAR NORTH YAKIMA, WASH.

The only important canal taking water from Naches River above the mouth of Tieton River is the Selah Valley canal. There are a few canals above the Selah Valley, but they are small private ditches and their combined flow would probably not exceed 15 second-feet.

The Selah Valley canal heads in Naches River on its left bank about 1 mile above the mouth of the Tieton, in sec. 35, T. 15 N., R. 16 E. With the exception of the Power canal it is the largest canal taking water from the Naches.

The gage is in a flume 1 mile below the head-gates. Measurements are made at the gage.

*Discharge measurements of Selah Valley canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 21 | W. J. Lightfoot | 23.8 | 2.80 | 2.50 | 66.5 |
| July 18 | do | 26.0 | 3.23 | 2.80 | 84.1 |
| August 3 | do | 24.6 | 3.37 | 2.65 | 83.0 |
| September 5 | do | 12.3 | 1.71 | 1.20 | 21.0 |
| October 10 | do | 13.5 | 1.89 | 1.40 | 25.6 |

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*Daily gage height, in feet, of Selah Valley canal near North Yakima, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Day. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 2.4 | 2.75 | 2.7 | 2.1 | 17 | ..... | 2.7 | 0.0 | 2.35 | 1.5 |
| 2 | ..... | 2.4 | 2.75 | ..... | 2.0 | 18 | 2.6 | 2.75 | 0.0 | 2.35 | 1.5 |
| 3 | ..... | 2.4 | 2.75 | ..... | 1.95 | 19 | 2.6 | 2.75 | 0.0 | 2.35 | 1.45 |
| 4 | ..... | 2.4 | 2.65 | ..... | 1.9 | 20 | 2.6 | 2.75 | 1.6 | 2.35 | 1.45 |
| 5 | ..... | 2.4 | 2.65 | 1.15 | 1.9 | 21 | 2.6 | 2.75 | 1.5 | 2.3 | 1.45 |
| 6 | ..... | 2.4 | 2.65 | 1.15 | 1.8 | 22 | 2.55 | 2.75 | 2.6 | 2.35 | 1.4 |
| 7 | ..... | 2.5 | 2.65 | 2.0 | 1.6 | 23 | 2.55 | 2.4 | 2.75 | 2.25 | 1.4 |
| 8 | ..... | 2.6 | 2.6 | 2.6 | 1.4 | 24 | 2.55 | 2.4 | 2.4 | 2.25 | 1.4 |
| 9 | ..... | 2.6 | 2.6 | 2.5 | 1.4 | 25 | 2.55 | 2.5 | 2.75 | 2.25 | 1.4 |
| 10 | ..... | 2.6 | 2.6 | 2.55 | 1.35 | 26 | 2.55 | 2.65 | 2.75 | 2.15 | 1.4 |
| 11 | ..... | 2.6 | 2.6 | 2.45 | 1.35 | 27 | 2.15 | 2.75 | 2.75 | 2.05 | 1.4 |
| 12 | ..... | 2.6 | 2.6 | 2.45 | 1.35 | 28 | 2.4 | 2.75 | 2.75 | 2.1 | 1.4 |
| 13 | ..... | 2.6 | 2.7 | 2.5 | 1.35 | 29 | 2.4 | 2.75 | 2.75 | 2.1 | 1.4 |
| 14 | ..... | 2.6 | 2.7 | 2.45 | 1.35 | 30 | 2.4 | 2.75 | 2.75 | 2.1 | 1.5 |
| 15 | ..... | 2.65 | 2.75 | 2.45 | 1.4 | 31 | ..... | 2.75 | 2.75 | ..... | 1.5 |
| 16 | ..... | 2.7 | 2.75 | 2.4 | 1.4 | | | | | | |

## WAPATOX CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the left bank of Naches River opposite the mouth of Tieton River, in sec. 36, T. 15 N., R. 16 E. It is maintained by a stock company of 100 equal shares.

The gage is 200 feet below the head-gates. Measurements are made from a foot plank 100 feet below the gage.

*Discharge measurements of Wapatox canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 19 | W. C. Muldrow | 18.3 | 1.64 | 1.83 | 30.0 |
| July 18 | do | 28.0 | 1.93 | 2.67 | 54.0 |
| October 10 | do | 8.5 | .82 | .66 | 7.0 |

*Daily gage height, in feet, of Wapatox canal near North Yakima, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Day. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 2.0 | 2.5 | 2.75 | 0.65 | 17 | ..... | 2.6 | 0.0 | 2.5 | ..... |
| 2 | ..... | 2.0 | 2.4 | ..... | .65 | 18 | ..... | 2.6 | 0.0 | 2.4 | ..... |
| 3 | ..... | 2.25 | 2.4 | ..... | .65 | 19 | 2.35 | 2.75 | 0.0 | 2.5 | ..... |
| 4 | ..... | 2.25 | 2.3 | ..... | 1.15 | 20 | 2.35 | 2.9 | 2.9 | 2.35 | ..... |
| 5 | ..... | 2.1 | 2.25 | 2.65 | 1.0 | 21 | 2.35 | 2.9 | 2.85 | 2.65 | ..... |
| 6 | ..... | 2.35 | 2.15 | 2.65 | .65 | 22 | 2.35 | 2.85 | 2.9 | 2.4 | ..... |
| 7 | ..... | 2.35 | 2.15 | 2.35 | .65 | 23 | 2.25 | 2.85 | 2.85 | 2.4 | ..... |
| 8 | ..... | 2.65 | 2.25 | 2.6 | .65 | 24 | 2.25 | 2.4 | 2.9 | 2.4 | ..... |
| 9 | ..... | 2.75 | 2.25 | 2.6 | .65 | 25 | 2.25 | 2.25 | 2.85 | 2.35 | ..... |
| 10 | ..... | 2.95 | 2.5 | 2.65 | .65 | 26 | 2.25 | 2.4 | 2.85 | 2.35 | ..... |
| 11 | ..... | 2.65 | 2.5 | 2.6 | .65 | 27 | 2.0 | 2.4 | 2.8 | 2.1 | ..... |
| 12 | ..... | 2.5 | 2.85 | 2.6 | .65 | 28 | 2.0 | 2.4 | 3.1 | 2.0 | ..... |
| 13 | ..... | 2.6 | 2.75 | 2.65 | .65 | 29 | 2.0 | 2.4 | 2.75 | 1.9 | ..... |
| 14 | ..... | 2.65 | 2.65 | 2.6 | .65 | 30 | 1.9 | 2.4 | 2.85 | 1.9 | ..... |
| 15 | ..... | 2.6 | 2.25 | 2.5 | ..... | 31 | ..... | 2.6 | 2.65 | ..... | ..... |
| 16 | ..... | 2.65 | 2.75 | 2.4 | ..... | | | | | | |

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### FORTUNE CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the right bank of Naches River on John W. Foster's ranch, 16 miles from North Yakima. Its intake is near that of the Lower Scott canal.

The gage is at a wagon bridge on the road leading to the ford. Measurements are made from the bridge.

*Discharge measurements of Fortune canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 24 | W. C. Muldrow | 12.5 | 0.98 | ..... | 12.3 |
| August 16 | do | 7.7 | .60 | 1.60 | 4.7 |
| September 4 | do | 14.1 | 1.18 | 2.25 | 16.0 |
| October 9 | do | 8.2 | .48 | 1.50 | 4.0 |

*Daily gage height, in feet, of Fortune canal near North Yakima, Wash., for 1905.*

| Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.9 | 2.2 | 12 | ..... | 2.1 | .8 | 22 | 1.7 | 2.2 | ..... |
| 2 | ..... | 1.9 | 1.3 | 13 | ..... | 2.2 | .8 | 23 | 1.5 | 2.2 | ..... |
| 3 | ..... | 2.2 | 1.3 | 14 | ..... | 2.2 | .8 | 24 | 1.4 | 2.2 | ..... |
| 4 | ..... | 2.2 | 1.6 | 15 | ..... | 2.1 | .8 | 25 | 1.0 | 2.1 | ..... |
| 5 | ..... | 2.2 | 1.5 | 16 | 1.6 | 2.2 | 1.1 | 26 | 1.0 | 2.1 | ..... |
| 6 | ..... | 2.1 | 1.6 | 17 | 2.1 | 2.1 | 1.2 | 27 | 1.9 | 2.3 | ..... |
| 7 | ..... | 2.1 | 1.6 | 18 | 2.0 | 2.0 | 1.0 | 28 | 2.2 | 2.1 | ..... |
| 8 | ..... | 2.1 | 1.6 | 19 | 1.7 | 2.0 | 1.0 | 29 | 2.1 | 2.1 | ..... |
| 9 | ..... | 2.1 | 1.5 | 20 | 1.8 | 2.2 | 1.0 | 30 | 2.0 | 2.1 | ..... |
| 10 | ..... | 2.1 | 1.5 | 21 | 1.6 | 2.2 | 1.0 | 31 | 1.9 | ..... | ..... |
| 11 | ..... | 2.1 | 1.5 | | | | | | | | |

### LOWER SCOTT CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the right bank of Naches River on John W. Foster's ranch, 16 miles from North Yakima.

The gage is just below the crossing of the road leading to the ford. Measurements are taken from a footbridge near the gage.

*Discharge measurements of Lower Scott canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 24 | W. C. Muldrow | 9.9 | 1.40 | ..... | 14.3 |
| August 16 | do | 3.5 | .94 | 0.70 | 3.3 |
| September 4 | do | 11.5 | 1.75 | 1.35 | 20.2 |
| October 9 | do | 7.3 | 1.51 | 1.05 | 11.0 |

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*Daily gage height, in feet, of Lower Scott canal near North Yakima, Wash., for 1905.*

| Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0.8 | 1.1 | 12 | | 1.1 | 1.0 | 22 | .6 | 1.3 | |
| 2 | | .8 | 1.1 | 13 | | 1.2 | 1.0 | 23 | .6 | 1.3 | |
| 3 | | 1.6 | 1.1 | 14 | | 1.2 | 1.0 | 24 | .5 | 1.3 | |
| 4 | | 1.3 | 1.1 | 15 | | 1.1 | 1.0 | 25 | .4 | 1.0 | |
| 5 | | 1.1 | 1.1 | 16 | 0.7 | 1.2 | 1.2 | 26 | .4 | .9 | |
| 6 | | 1.1 | 1.1 | 17 | 1.0 | 1.0 | 1.2 | 27 | .8 | 1.0 | |
| 7 | | 1.1 | 1.1 | 18 | 1.0 | 1.0 | 1.1 | 28 | 1.1 | .9 | |
| 8 | | 1.1 | 1.1 | 19 | .8 | 1.0 | 1.1 | 29 | .9 | .9 | |
| 9 | | 1.1 | 1.1 | 20 | .9 | 1.2 | 1.1 | 30 | .9 | .9 | |
| 10 | | 1.1 | 1.1 | 21 | .7 | 1.2 | 1.1 | 31 | .8 | | |
| 11 | | 1.1 | 1.0 | | | | | | | | |

### CLARK CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the left bank of Naches River, on D. R. Putnam's ranch, about 16 miles from North Yakima.

The gage is one-half mile below the head-gate. Measurements are made from a foot plank near the gage.

*Discharge measurements of Clark canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 21 | W. C. Muldrow | 6.2 | 1.42 | | 8.8 |
| September 4 | do | 10.0 | 1.63 | 1.35 | 16.3 |
| October 11 | do | 7.2 | .70 | .75 | 5.0 |

*Daily gage height, in feet, of Clark canal near North Yakima, Wash., for 1905.*

| Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 1.4 | | 12 | | 1.3 | 1.0 | 22 | 1.4 | 1.4 | .8 |
| 2 | | 1.7 | 1.3 | 13 | | 1.5 | 1.0 | 23 | 1.4 | 1.4 | |
| 3 | | 1.5 | 1.5 | 14 | | 1.5 | 1.0 | 24 | 1.4 | | |
| 4 | | 1.5 | 1.7 | 15 | | 1.4 | | 25 | 1.4 | 1.5 | |
| 5 | | 1.05 | 1.7 | 16 | | 1.4 | 1.0 | 26 | 1.4 | 1.5 | |
| 6 | | 1.4 | 1.6 | 17 | 1.6 | | .9 | 27 | | 1.5 | |
| 7 | | 1.3 | 1.6 | 18 | 1.5 | 1.3 | .9 | 28 | 1.6 | 1.4 | |
| 8 | | 1.3 | | 19 | 1.5 | 1.3 | .9 | 29 | 1.5 | 1.3 | |
| 9 | | 1.4 | 1.1 | 20 | | 1.3 | .8 | 30 | 1.5 | 1.2 | |
| 10 | | | 1.1 | 21 | 1.4 | 1.4 | .8 | 31 | 1.4 | | |
| 11 | | 1.3 | 1.0 | | | | | | | | |

### LOWERY CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the left bank of Naches River, about 16 miles from North Yakima.

The gage is at a bridge about 1,200 feet from Harry Painter's store. Measurements are made in a flume about 800 feet above the gage.

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*Discharge measurements of Lowery canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 21 | W. C. Muldrow | 12.8 | 1.41 | 2.20 | 18.0 |
| August 16 | do | 12.2 | 1.01 | 2.15 | 12.3 |
| September 4 | do | 13.3 | 1.74 | 2.85 | 23.1 |
| October 11 | do | 9.8 | 1.76 | 2.35 | 17.2 |

*Daily gage height, in feet, of Lowery canal near North Yakima, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Nov. | Day. | June. | July. | Aug. | Sept. | Oct. | Nov. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2.2 | 2.3 | 2.4 | 2.3 | 2.3 | 17 | | 2.3 | 2.4 | 2.3 | 2.3 | 2.4 |
| 2 | | 2.1 | 2.3 | 2.4 | 2.3 | 2.3 | 18 | | 2.3 | 2.3 | 2.3 | 2.3 | 2.4 |
| 3 | | 2.1 | 2.3 | 2.4 | 2.3 | 2.3 | 19 | | 2.3 | 2.3 | 2.3 | 2.3 | 2.4 |
| 4 | | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 20 | | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 |
| 5 | | 2.1 | 2.2 | 2.3 | 2.3 | 2.3 | 21 | 2.2 | 2.3 | 2.2 | 2.3 | 2.3 | 2.3 |
| 6 | | 2.1 | 2.2 | 2.3 | 2.3 | 2.4 | 22 | 2.2 | 2.3 | 2.2 | 2.4 | 2.3 | 2.3 |
| 7 | | 2.2 | 2.2 | 2.3 | 2.3 | 2.4 | 23 | 2.1 | 2.0 | 2.1 | 2.4 | 2.3 | 2.3 |
| 8 | | 2.2 | 2.1 | 2.3 | 2.3 | 2.3 | 24 | 2.2 | 2.0 | 2.1 | 2.3 | 2.3 | 2.3 |
| 9 | | 2.1 | 2.1 | 2.2 | 2.3 | 2.4 | 25 | 2.3 | 2.3 | 2.1 | 2.3 | 2.3 | 2.3 |
| 10 | | 2.2 | 2.1 | 2.2 | 2.3 | 2.4 | 26 | 2.4 | 2.4 | 2.1 | 2.3 | 2.3 | 2.3 |
| 11 | | 2.2 | 2.1 | 2.3 | 2.3 | 2.4 | 27 | 2.2 | 2.3 | 2.1 | 2.3 | 2.3 | 2.3 |
| 12 | | 2.2 | 2.1 | 2.3 | 2.3 | 2.4 | 28 | 2.2 | 2.3 | 2.1 | 2.3 | 2.3 | 2.3 |
| 13 | | 2.1 | 2.1 | 2.3 | 2.3 | 2.4 | 29 | 2.2 | 2.3 | 2.5 | 2.3 | 2.3 | 2.2 |
| 14 | | 2.0 | 2.1 | 2.3 | 2.3 | 2.4 | 30 | 2.2 | 2.2 | 2.5 | 2.3 | 2.3 | 2.2 |
| 15 | | 2.2 | 2.1 | 2.3 | 2.3 | 2.4 | 31 | | 2.2 | 2.4 | | 2.3 | |
| 16 | | 2.2 | 2.3 | 2.3 | 2.3 | 2.4 | | | | | | | |

### GLEED CANAL NEAR NORTH YAKIMA, WASH.

This is the next large canal below the Wapatox. Its intake is on the left bank of Naches River, about 12 miles from North Yakima, in sec. 24, T. 14 N., R. 17 E.

The gage is about three-eighths mile below the head-gates, on Edward Kershaw's ranch, and 600 feet above the forks of the canal. Measurements are made from a foot plank near the gage.

*Discharge measurements of Gleed canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet* | *Second-feet.* |
| June 22 | W. C. Muldrow | 43.5 | 1.92 | 2.20 | 83.9 |
| July 10 | do | 45.0 | 1.62 | 2.40 | 73.0 |
| July 19 | do | 43.0 | 1.72 | 2.08 | 74.0 |
| August 5 | do | 48.0 | 1.65 | 2.37 | 79.0 |
| September 6 | do | 37.0 | 1.40 | 1.65 | 51.6 |
| October 31 | do | 2.75 | 2.76 | .25 | 7.6 |

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*Daily gage height, in feet, of Gleed canal near North Yakima, Wash., for 1905.*

| Day. | May. | June. | July. | Aug. | Sept. | Day. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2.4 | 1.6 | 1.9 | 1.85 | 17 | | 2.1 | 2.1 | 2.0 | 1.25 |
| 2 | | 2.25 | 2.0 | 2.0 | 1.85 | 18 | | 2.1 | 2.1 | 2.0 | 1.25 |
| 3 | | 2.35 | 2.0 | 2.0 | 1.85 | 19 | | 2.1 | 2.1 | 2.0 | 1.25 |
| 4 | | 2.35 | 2.0 | 2.0 | 1.85 | 20 | | 2.1 | 2.1 | 2.0 | 1.25 |
| 5 | | 1.50 | 2.1 | 2.0 | 1.85 | 21 | | 1.5 | 2.35 | 1.9 | |
| 6 | | 1.50 | 2.15 | 2.0 | 1.65 | 22 | 2.0 | 1.5 | 2.35 | 1.85 | |
| 7 | | | 2.15 | 2.0 | 1.65 | 23 | 2.0 | 1.5 | 2.4 | 1.85 | |
| 8 | | | 2.15 | 2.0 | 1.65 | 24 | 2.0 | 1.5 | 2.25 | 1.9 | |
| 9 | | | 2.15 | 2.0 | 1.65 | 25 | 2.0 | 1.5 | 2.25 | 1.9 | |
| 10 | | | 2.25 | 2.0 | 1.65 | 26 | 2.0 | 1.5 | 2.1 | 1.85 | |
| 11 | | | 2.25 | 2.0 | 1.65 | 27 | 2.0 | 1.5 | 2.0 | 1.85 | |
| 12 | | 1.75 | 1.6 | 2.0 | 1.65 | 28 | 2.1 | 1.5 | 2.0 | 1.85 | |
| 13 | | 1.75 | 1.60 | 2.0 | 1.85 | 29 | 2.15 | 1.5 | 2.0 | 1.85 | |
| 14 | | 2.0 | 2.0 | 2.0 | 1.85 | 30 | 2.15 | 1.6 | 2.0 | 1.85 | |
| 15 | | 2.0 | 2.1 | 2.1 | 1.25 | 31 | 2.4 | | 2.1 | 1.85 | |
| 16 | | 2.0 | 2.1 | 2.1 | 1.25 | | | | | | |

*Discharge measurements of Gleed canal wasteway near North Yakima, Wash., in 1905.*[a]

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet* | *Second-feet.* |
| July 10 | W. J. Lightfoot | 21 | 29 | 1.24 | | 36 |
| July 19 | do | 16 | 16 | 2.44 | 1.40 | 39 |

[a] Includes waste from all canals on north side of Naches River.

*Daily gage height, in feet, of Gleed canal wasteway near North Yakima, Wash., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Day. | July. | Aug. | Sept. | Oct. | Day. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 1.4 | 1.1 | 1.0 | 12 | | 1.2 | 1.1 | 1.3 | 22 | 2.4 | 1.4 | 1.0 | |
| 2 | | 1.4 | 1.1 | 1.2 | 13 | | 1.3 | 1.1 | 1.4 | 23 | 1.8 | 1.4 | 1.1 | |
| 3 | | 1.2 | 1.2 | 1.1 | 14 | | 1.3 | 1.1 | 1.3 | 24 | 1.5 | 1.4 | 1.1 | |
| 4 | | 1.0 | 1.2 | 1.2 | 15 | | 1.2 | 1.1 | 1.0 | 25 | 1.3 | 1.4 | 1.1 | |
| 5 | | 1.3 | 1.1 | 1.4 | 16 | | 1.2 | 1.1 | 1.0 | 26 | 1.3 | 1.4 | 1.1 | |
| 6 | | 1.4 | 1.2 | 1.5 | 17 | | 1.4 | 1.1 | 1.0 | 27 | 1.5 | 1.4 | 1.1 | |
| 7 | | 1.4 | 1.1 | 1.5 | 18 | | 1.4 | 1.1 | 1.0 | 28 | 1.4 | 1.4 | 1.0 | |
| 8 | | 1.3 | 1.1 | 1.2 | 19 | 1.4 | 1.4 | 1.0 | .8 | 29 | 1.4 | 1.5 | 1.0 | |
| 9 | | 1.2 | 1.1 | 1.3 | 20 | 1.3 | 1.3 | 1.0 | .7 | 30 | 1.3 | 1.5 | 1.1 | |
| 10 | | 1.3 | 1.2 | 1.3 | 21 | 1.3 | 1.4 | 1.0 | .7 | 31 | 1.2 | 1.1 | | |
| 11 | | 1.3 | 1.2 | 1.4 | | | | | | | | | | |

## YAKIMA VALLEY CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the right bank of Naches River, 11 miles from North Yakima, in sec. 24, T. 14 N., R. 17 E.

The gage is in a flume 200 feet below the head-gates. Measurements are made from a footbridge 60 feet above the gage.

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*Discharge measurements of Yakima Valley canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 24 | W. C. Muldrow | 24.8 | 2.05 | 2.25 | 58.4 |
| August 9 | do | 24.4 | 2.99 | 2.35 | 73.0 |
| September 11 | do | | | 2.05 | 54.6 |
| October 9 | do | 15.3 | 2.0 | 1.35 | 30.7 |

*Daily gage height, in feet, of Yakima Valley canal near North Yakima, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Oct. | Day. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2.35 | 2.3 | 2.25 | 1.7 | 17 | | 2.65 | 2.2 | 1.95 | |
| 2 | | 2.35 | 2.3 | 2.25 | 1.65 | 18 | | 2.65 | 2.2 | 1.9 | |
| 3 | | 2.35 | 2.3 | 2.15 | 1.65 | 19 | | 2.9 | 2.2 | 1.85 | |
| 4 | | 2.35 | | 2.15 | 1.65 | 20 | | 2.75 | 2.2 | 1.85 | |
| 5 | | 2.35 | 1.95 | 2.15 | 1.65 | 21 | | 2.3 | 2.2 | 1.8 | |
| 6 | | 2.4 | 1.95 | 2.15 | 1.45 | 22 | | 2.25 | 2.2 | 1.85 | |
| 7 | | 2.45 | 1.95 | 2.15 | 1.45 | 23 | | 2.25 | 2.2 | 1.75 | |
| 8 | | 2.5 | 2.15 | 2.1 | 1.45 | 24 | 2.3 | 2.25 | 2.2 | 1.75 | |
| 9 | | 2.55 | 2.2 | 2.1 | 1.45 | 25 | 2.3 | 2.25 | 2.1 | 1.75 | |
| 10 | | 2.65 | 2.2 | 2.1 | 1.45 | 26 | 2.35 | 2.5 | 2.0 | 1.75 | |
| 11 | | 2.65 | 2.2 | 2.05 | 1.45 | 27 | 2.3 | 2.3 | 2.2 | 1.75 | |
| 12 | | 2.65 | 2.2 | 2.05 | 1.45 | 28 | 2.3 | 2.3 | 2.25 | 1.7 | |
| 13 | | 2.65 | 2.2 | 2.05 | 1.45 | 29 | 2.3 | 2.3 | 2.25 | 1.7 | |
| 14 | | 2.65 | 2.15 | 2.05 | 1.45 | 30 | 2.35 | 2.3 | 2.25 | 1.7 | |
| 15 | | 2.6 | 2.15 | 2.05 | | 31 | | 2.3 | 2.25 | | |
| 16 | | 2.65 | 2.1 | 2.0 | | | | | | | |

### WHITE & LEACH CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the left bank of Naches River about 10 miles from North Yakima. The gage is at a wagon bridge on White's ranch. Measurements are made from a footbridge 200 feet above the gage.

*Discharge measurements of White & Leach canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 22 | W. C. Muldrow | 4.7 | 2.32 | | 10.9 |
| August 18 | do | 7.9 | 1.28 | 1.40 | 10.1 |
| September 12 | do | 4.86 | 1.22 | 1.05 | 6.0 |

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*Daily gage height, in feet, of White & Leach canal near North Yakima, Wash., for 1905.*

| Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0.8 | 1.1 | 12 | | 0.9 | 0.2 | 22 | 1.3 | 1.2 | |
| 2 | | 1.4 | 1.3 | 13 | | 1.3 | .2 | 23 | 1.2 | 1.1 | |
| 3 | | 1.5 | 1.3 | 14 | | 1.3 | .1 | 24 | 1.2 | 1.2 | |
| 4 | | 1.3 | 1.3 | 15 | | 1.0 | | 25 | 1.2 | 1.2 | |
| 5 | | 1.4 | 1.3 | 16 | | .9 | | 26 | 1.2 | 1.3 | |
| 6 | | 1.2 | .8 | 17 | | .9 | | 27 | 1.0 | 1.3 | |
| 7 | | 1.2 | .5 | 18 | | 1.4 | .9 | 28 | 1.4 | 1.3 | |
| 8 | | 1.3 | .4 | 19 | | 1.4 | .7 | 29 | 1.2 | 1.2 | |
| 9 | | 1.2 | .3 | 20 | | 1.4 | .9 | 30 | 1.1 | 1.1 | |
| 10 | | 1.2 | .3 | 21 | | 1.4 | 1.1 | 31 | .9 | | |
| 11 | | 1.0 | .2 | | | | | | | | |

## McCORMICK CANAL NEAR NORTH YAKIMA, WASH.

This canal heads in the left bank of Naches River about 9 miles from North Yakima.

The gage is close to the road on the lower branch of the White & Leach canal, which supplies the McCormick canal after July 1. Measurements are made in a flume 300 feet below the gage.

*Discharge measurements of McCormick canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 22 | W. C. Muldrow | 4.75 | 1.76 | | 8.4 |
| August 18 | do | 5.2 | 2.25 | 1.50 | 11.7 |
| September 12 | do | 6.8 | .70 | .95 | 4.6 |

*Daily gage height, in feet, of McCormick canal near North Yakima, Wash., for 1905.*

| Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0.9 | 1.0 | 12 | | 1.0 | 0.6 | 22 | 1.2 | 1.2 | |
| 2 | | 1.1 | 1.3 | 13 | | 1.2 | .5 | 23 | 1.2 | 1.2 | |
| 3 | | 1.2 | 1.4 | 14 | | 1.2 | .5 | 24 | 1.2 | 1.2 | |
| 4 | | 1.0 | 1.4 | 15 | | 1.1 | .5 | 25 | 1.1 | 1.2 | |
| 5 | | 1.1 | 1.4 | 16 | | 1.0 | | 26 | 1.1 | 1.4 | |
| 6 | | 1.0 | .8 | 17 | | 1.0 | | 27 | 1.0 | 1.3 | |
| 7 | | .9 | .7 | 18 | 1.5 | 1.0 | | 28 | 1.2 | 1.2 | |
| 8 | | 1.0 | .7 | 19 | 1.5 | 1.0 | | 29 | 1.1 | 1.1 | |
| 9 | | 1.0 | .7 | 20 | 1.5 | 1.1 | | 30 | 1.0 | 1.1 | |
| 10 | | 1.0 | .6 | 21 | 1.4 | 1.2 | | 31 | .9 | | |
| 11 | | .9 | .6 | | | | | | | | |

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### NACHES-COWICHE CANAL NEAR NORTH YAKIMA, WASH.

The intake of this canal is on the right bank of Naches River just below Nelson's bridge at Painted Rocks, in sec. 9, T. 13 N., R. 18 E. About three-eighths of a mile below the intake the canal crosses Cowiche Creek and until about June 1 takes nearly all its water from this source. The amount of water taken from the river gradually increases until about August 1, after which date the entire flow of the canal is drawn from Naches River.

The gage is in a flume on T. B. Nelson's place about one-half mile below the head-gates. Measurements are made from a foot plank near the gage.

*Discharge measurements of Naches-Cowiche canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet* | *Second-feet.* |
| June 22 | W. C. Muldrow | 21.7 | 1.86 | 3.09 | 40.1 |
| July 11 | do | 23.0 | 1.91 | 3.18 | 44.0 |
| August 9 | do | 22.4 | 2.01 | 3.17 | 45.0 |
| September 15 | do | 14.4 | 1.58 | 2.35 | 22.7 |
| September 29 | do | 15.0 | 1.13 | 2.10 | 16.8 |

*Daily gage height, in feet, of Naches-Cowiche canal near North Yakima, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2.35 | 3.25 | 3.0 | 12 | | 3.35 | 3.15 | 2.65 | 22 | 3.1 | 3.25 | 3.15 | 2.3 |
| 2 | | 2.35 | 3.2 | 2.75 | 13 | | 3.25 | 3.2 | 2.6 | 23 | 3.0 | 3.25 | 3.15 | 2.25 |
| 3 | | 2.35 | 3.2 | 3.0 | 14 | | 3.25 | 3.15 | 2.25 | 24 | 2.4 | 3.25 | 3.15 | 2.3 |
| 4 | | 2.35 | 3.25 | 3.0 | 15 | | 3.25 | 3.15 | 2.25 | 25 | 2.4 | 3.25 | 3.15 | 2.3 |
| 5 | | 2.5 | 3.25 | 3.0 | 16 | | 3.25 | 3.15 | 2.25 | 26 | 2.4 | 3.25 | 3.15 | 2.15 |
| 6 | | 3.0 | 3.25 | 3.0 | 17 | | 3.25 | 3.15 | 2.3 | 27 | 2.5 | 3.25 | 3.15 | 2.2 |
| 7 | | 3.0 | 3.25 | 2.75 | 18 | | 3.25 | 3.15 | 0.0 | 28 | 2.5 | 3.25 | 3.15 | 2.15 |
| 8 | | 3.1 | 3.25 | 2.75 | 19 | | 3.2 | 3.15 | 2.25 | 29 | 2.5 | 3.25 | 3.1 | 2.1 |
| 9 | | 3.25 | 3.25 | 2.75 | 20 | | 3.2 | 3.15 | 2.25 | 30 | 2.25 | 3.25 | 3.1 | 2.1 |
| 10 | | 3.25 | 3.2 | 2.75 | 21 | | 3.25 | 3.15 | 2.3 | 31 | | 3.25 | 3.0 | |
| 11 | | 3.25 | 3.25 | 2.75 | | | | | | | | | | |

### BROADGAUGE CANAL NEAR NORTH YAKIMA, WASH.

This canal is supplied from the wasteway of the Power canal. The gage is about 500 feet below the head-gates, at a bridge from which measurements are made.

*Discharge measurements of Broadgauge canal near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 23 | W. C. Muldrow | 2.65 | 1.29 | | 3.4 |
| August 1 | do | 8.00 | .84 | 1.25 | 6.7 |
| August 12 | do | 9.10 | .90 | 1.45 | 8.2 |
| September 29 | do | 5.60 | .69 | 1.00 | 3.9 |



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*Daily gage height, in feet, of Broadgauge canal near North Yakima, Wash., for 1905.*

| Day. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
|---|---|---|---|---|---|---|---|
| 1 | | 1.5 | 1.6 | 1.0 | 1.6 | 1.35 | 0.85 |
| 2 | | 1.5 | 1.5 | 1.0 | 1.6 | 1.0 | .85 |
| 3 | | 1.25 | 1.65 | 1.45 | 1.0 | 1.0 | .85 |
| 4 | | .7 | 1.65 | 1.45 | .5 | .9 | .85 |
| 5 | | 1.6 | 1.65 | 1.75 | .75 | .9 | .85 |
| 6 | | 1.0 | 1.5 | 1.75 | 1.5 | .9 | .85 |
| 7 | | .95 | 1.75 | 1.58 | 1.5 | .9 | .85 |
| 8 | | 1.0 | 1.5 | 1.75 | 1.65 | .9 | .85 |
| 9 | | 1.45 | .35 | 1.8 | 1.5 | .9 | .85 |
| 10 | | 1.3 | .35 | 1.85 | .9 | .9 | .85 |
| 11 | | .75 | 1.5 | 1.4 | 1.65 | .9 | .9 |
| 12 | | .6 | 1.5 | 1.4 | 1.6 | .9 | .9 |
| 13 | | .6 | 1.65 | 1.35 | 1.6 | .9 | .9 |
| 14 | | .6 | 1.65 | 1.4 | 1.75 | .9 | .9 |
| 15 | | 1.0 | 1.65 | 1.4 | 1.6 | .9 | .9 |
| 16 | | 1.0 | 1.65 | 1.4 | 1.4 | .9 | .9 |
| 17 | | 1.65 | 1.65 | 1.15 | .84 | .9 | .9 |
| 18 | | 1.4 | 1.65 | 1.5 | .84 | .9 | .9 |
| 19 | | 1.75 | 1.5 | 1.35 | 1.35 | .9 | .9 |
| 20 | | 1.7 | 1.25 | 1.35 | 1.35 | .85 | .9 |
| 21 | | 1.7 | 1.25 | 1.0 | 1.35 | .85 | .9 |
| 22 | | 1.7 | 1.4 | .85 | 1.35 | .85 | .9 |
| 23 | | 1.75 | 1.0 | 1.75 | 1.35 | .85 | .9 |
| 24 | | .5 | 1.0 | 1.85 | 1.35 | .85 | .9 |
| 25 | | 1.7 | 1.15 | 1.9 | 1.35 | .85 | .9 |
| 26 | 1.4 | 1.7 | .9 | 1.85 | 1.35 | .85 | .6 |
| 27 | 1.5 | 1.5 | 1.15 | 1.85 | 1.35 | .85 | .85 |
| 28 | 1.5 | 1.5 | 1.25 | 1.85 | 1.35 | .85 | .65 |
| 29 | 1.5 | 1.5 | 1.25 | 1.75 | 1.0 | .9 | ..... |
| 30 | 1.5 | 1.5 | 1.5 | 1.6 | 1.7 | .85 | ..... |
| 31 | 1.5 | ..... | 1.42 | 1.6 | ..... | .85 | ..... |

## POWER CANAL AT NORTH YAKIMA, WASH.

This canal heads in Naches River on its right bank in sec. 10, T. 13 N., R. 18 E., about 4 miles from North Yakima. Previous to October, 1904, it was known as the Yakima Valley Light and Power Company canal. It is now the property of the Northwestern Light and Water Company, and is the largest canal taking water from Naches River. The new company now controls also the Shanno and Broadgauge canals. These two canals and the Union canal cross the Power canal, and during the summer are supplied chiefly by it. The wasteway of this canal discharges into Yakima River.

The gage is just below the regulating gates. Measurements are made at the regulating gates and at a small flume which crosses the canal a short distance below the gage.

*Discharge measurements of Power canal at North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 23 | W. J. Lightfoot | 80 | 2.23 | 2.83 | 180 |
| August 10 | do | 75 | 2.40 | 2.85 | 180 |

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*Daily gage height, in feet, of Power canal at North Yakima, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 2.65 | 2.75 | 2.65 | 12 | ..... | 2.0 | 2.65 | 2.65 | 22 | ..... | 2.75 | 2.65 | 2.75 |
| 2 | ..... | 2.65 | 2.75 | 2.65 | 13 | ..... | 2.35 | 2.65 | 2.65 | 23 | 2.85 | 2.75 | 2.65 | 2.65 |
| 3 | ..... | 2.65 | 2.75 | 2.65 | 14 | ..... | 2.75 | 2.65 | 2.65 | 24 | 2.65 | 2.75 | 2.65 | 2.65 |
| 4 | ..... | 2.65 | 2.75 | 2.65 | 15 | ..... | 2.65 | 2.65 | 2.65 | 25 | 2.65 | 2.65 | 2.65 | 2.65 |
| 5 | ..... | 2.65 | 2.75 | 2.65 | 16 | ..... | 2.65 | 2.65 | 2.65 | 26 | 2.65 | 2.65 | 2.65 | 2.65 |
| 6 | ..... | 2.65 | 2.8 | 2.65 | 17 | ..... | 2.65 | 2.65 | 2.65 | 27 | 2.65 | 2.75 | 2.65 | 2.65 |
| 7 | ..... | 2.65 | 2.8 | 2.65 | 18 | ..... | 2.65 | 2.65 | 2.65 | 28 | 2.65 | 2.75 | 2.65 | 2.65 |
| 8 | ..... | 1.35 | 3.0 | 2.65 | 19 | ..... | 2.65 | 2.65 | 2.65 | 29 | 2.65 | 2.75 | 2.65 | 2.65 |
| 9 | ..... | 1.35 | 2.65 | 2.65 | 20 | ..... | 2.75 | 2.65 | 2.75 | 30 | 2.65 | 2.75 | 2.65 | 2.65 |
| 10 | ..... | 1.35 | 2.65 | 2.65 | 21 | ..... | 2.75 | 2.65 | 2.75 | 31 | ..... | 2.75 | 2.65 | ..... |
| 11 | ..... | 1.35 | 2.65 | 2.65 | | | | | | | | | | |

## SHANNO CANAL AT NORTH YAKIMA, WASH.

This canal is supplied from the wasteway of the Power canal. The gage is near a bridge about 1,200 feet below the head-gates. Measurements are made from a foot plank about 100 feet below the gage.

*Discharge measurements of Shanno canal at North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 12 | W. C. Muldrow | 19.5 | 1.66 | 2.10 | 32.4 |
| September 1 | do | 15.3 | 1.00 | 1.60 | 15.4 |
| September 29 | do | 10.9 | .47 | 1.25 | 5.2 |

*Daily gage height, in feet, of Shanno canal at North Yakima, Wash., for 1905.*

| Day. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
|---|---|---|---|---|---|---|---|
| 1 | ..... | 2.1 | 1.0 | 1.85 | 2.35 | 1.2 | 1.15 |
| 2 | ..... | 2.1 | 1.0 | 1.85 | 2.35 | 1.2 | 1.15 |
| 3 | ..... | 1.65 | 1.9 | 1.85 | 2.25 | 1.2 | 1.1 |
| 4 | ..... | 1.65 | 1.9 | 1.85 | 2.2 | 1.2 | 1.1 |
| 5 | ..... | 1.0 | 1.9 | 1.85 | 1.8 | 1.2 | 1.0 |
| 6 | ..... | 1.0 | 2.0 | 1.85 | 1.8 | 1.2 | 1.1 |
| 7 | ..... | 1.0 | 1.9 | 1.85 | 1.8 | 1.2 | 1.1 |
| 8 | ..... | 1.0 | 2.0 | 1.85 | 1.8 | 1.2 | 1.1 |
| 9 | ..... | 1.0 | 2.0 | 1.85 | 1.8 | 1.1 | 1.1 |
| 10 | ..... | 1.0 | 2.0 | 2.0 | 1.75 | 1.1 | 1.1 |
| 11 | ..... | 1.75 | 2.25 | 2.0 | 1.8 | 1.1 | 1.1 |
| 12 | ..... | 1.75 | 2.25 | 2.1 | 1.85 | 1.15 | 1.1 |
| 13 | ..... | 1.8 | 2.35 | 2.35 | 1.85 | 1.1 | 1.1 |
| 14 | ..... | 1.5 | 2.35 | 2.5 | 1.8 | 1.15 | 1.1 |
| 15 | ..... | 1.4 | 2.25 | 2.4 | 1.85 | 1.2 | 1.1 |
| 16 | ..... | 1.4 | 2.25 | 2.4 | 1.85 | 1.15 | 1.1 |
| 17 | ..... | 1.6 | 2.25 | 2.4 | 1.85 | 1.15 | 1.05 |
| 18 | ..... | 1.6 | 2.25 | 2.25 | 1.9 | 1.1 | 1.05 |
| 19 | ..... | 1.6 | 2.25 | 2.25 | 1.8 | 1.1 | 1.05 |
| 20 | ..... | 1.9 | 2.25 | 2.25 | 1.25 | 1.15 | 1.05 |
| 21 | ..... | 1.9 | 2.25 | 2.15 | 1.25 | 1.2 | 1.05 |

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*Daily gage height, in feet, of Shanno canal at North Yakima, Wash., for 1905*—Continued.

| Day. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
|---|---|---|---|---|---|---|---|
| 22 | ..... | 2.25 | 2.25 | 2.1 | 1.25 | 1.15 | 1.05 |
| 23 | ..... | 2.4 | 2.25 | 2.0 | 1.25 | 1.15 | 1.0 |
| 24 | ..... | 2.5 | 2.35 | 2.0 | 1.2 | 1.15 | 1.05 |
| 25 | ..... | 2.25 | 2.35 | 2.0 | 1.2 | 1.2 | 1.0 |
| 26 | 1.0 | 1.6 | 2.0 | 2.0 | 1.2 | 1 2 | .8 |
| 27 | 1.9 | 1.6 | 2.0 | 2.0 | 1.2 | 1.2 | .8 |
| 28 | 2.0 | 1.0 | 1.5 | 2.0 | 1.25 | 1.2 | 1.0 |
| 29 | 1.9 | 1.0 | 1.5 | 1.25 | 1.2 | 1.15 | ..... |
| 30 | 2.0 | 1.0 | 1.8 | 1.75 | 1.2 | 1.15 | ..... |
| 31 | 2.1 | ..... | 1.85 | 1.75 | ..... | 1.15 | ..... |

## UNION CANAL AT NORTH YAKIMA, WASH.

This canal heads in Naches River on the right bank in sec. 11, T. 13 N., R. 18 E. In sec. 13 the Union canal crosses the wasteway of the Power canal and takes some additional water from it.

The gage is just below the head-gates. Measurements are made at the end of the flume a short distance below the gage.

*Discharge measurements of Union canal at North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 11 | W. C. Muldrow | 22.0 | 2.27 | 1.66 | 50.0 |
| August 19 | do | 23.0 | 1.79 | 1.66 | 42.0 |
| September 15 | do | 24.0 | 1 30 | 1.50 | 31.2 |

*Daily gage height, in feet, of Union canal at North Yakima, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.15 | 1.5 | 1.5 | 12 | ..... | 1.15 | 1.6 | 1.5 | 22 | ..... | 1.5 | 1.5 | 1.5 |
| 2 | ..... | 1.15 | 1.5 | 1.5 | 13 | ..... | 1.15 | 1.6 | 1.4 | 23 | ..... | 1.5 | 1.5 | 1.5 |
| 3 | ..... | 1.15 | 1.5 | 1.5 | 14 | ..... | 1.15 | 1.6 | 1.4 | 24 | 1.35 | 1.5 | 1.5 | 1.5 |
| 4 | ..... | 1.15 | 1.5 | 1.5 | 15 | ..... | 1.15 | 1.6 | 1.4 | 25 | 1.35 | 1.65 | 1.5 | 1.5 |
| 5 | ..... | 1.0 | 1.6 | 1.5 | 16 | ..... | 1.15 | 1.5 | 1.4 | 26 | 1.35 | 1.65 | 1.5 | 1.5 |
| 6 | ..... | 1.0 | 1.6 | 1.5 | 17 | ..... | 1.35 | 1.5 | 1.35 | 27 | 1.35 | 1.65 | 1.5 | 1.5 |
| 7 | ..... | 1.0 | 1.5 | 1.5 | 18 | ..... | 1.4 | 1.5 | 1.35 | 28 | 1.35 | 1.65 | 1.5 | 1.5 |
| 8 | ..... | 1.0 | 1.5 | 1.5 | 19 | ..... | 1.35 | 1.5 | 1.35 | 29 | 1.15 | 1.6 | 1.5 | 1.5 |
| 9 | ..... | 1.0 | 1.6 | 1.5 | 20 | ..... | 1.35 | 1.5 | 1.4 | 30 | 1.15 | 1.35 | 1.5 | 1.5 |
| 10 | ..... | 1.0 | 1.65 | 1.5 | 21 | ..... | 1.35 | 1.5 | 1.5 | 31 | ..... | 1.35 | 1.5 | ..... |
| 11 | ..... | 1.0 | 1.6 | 1.5 | | | | | | | | | | |

## TOWN CANAL AT NORTH YAKIMA, WASH.

This canal heads in Naches River in the right bank, one-eighth mile above the Northern Pacific Railway bridge and three-fourths mile above the mouth of the river.

The gage is near A. M. Cole's house, one-half mile below the headworks. Measurements are made from a foot plank near the gage.

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*Discharge measurements of Town canal at North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 23 | W. C. Muldrow | 13.2 | 1.24 | 1.83 | 16.6 |
| August 11 | do | 18.4 | 1.14 | 2.17 | 21.0 |
| September 23 | do | 12.0 | 1.22 | 1.70 | 14.6 |

*Daily gage height, in feet, of Town canal at North Yakima, Wash., for 1905.*

| Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. | Day. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 1.85 | 1.65 | 2.05 | 12 | | 1.6 | 1.9 | 1.9 | 22 | | 2.0 | 2.5 | 1.75 |
| 2 | | 1.85 | 1.7 | 2.0 | 13 | | 1.6 | 1.9 | 1.9 | 23 | 1.85 | 2.15 | 1.9 | 1.75 |
| 3 | | 1.75 | 1.85 | 2.0 | 14 | | 2.15 | 1.75 | 1.75 | 24 | 1.9 | 2.15 | 1.75 | 1.85 |
| 4 | | 1.75 | 1.65 | 1.9 | 15 | | 2.15 | 1.6 | 1.6 | 25 | 1.85 | 2.1 | 1.6 | 1.85 |
| 5 | | 1.7 | 1.4 | 1.9 | 16 | | 2.15 | 1.4 | 1.4 | 26 | 1.85 | 1.9 | 1.4 | 1.85 |
| 6 | | 1.65 | 1.4 | 1.85 | 17 | | 2.15 | 1.35 | 1.35 | 27 | 1.85 | 1.85 | 1.5 | 1.9 |
| 7 | | 1.65 | 1.4 | 1.8 | 18 | | 2.1 | 2.5 | 1.25 | 28 | 1.9 | 0.0 | 2.4 | 1.8 |
| 8 | | 1.65 | 1.75 | 1.85 | 19 | | 2.0 | 2.5 | 1.25 | 29 | 1.9 | 1.85 | 2.05 | 1.75 |
| 9 | | 1.6 | 2.35 | 1.85 | 20 | | 2.0 | 2.5 | 1.6 | 30 | 1.85 | 1.85 | 2.1 | |
| 10 | | 2.15 | 2.35 | 1.85 | 21 | | 2.0 | 2.5 | 1.75 | 31 | | 1.65 | 2.1 | |
| 11 | | 1.9 | 2.3 | 1.85 | | | | | | | | | | |

*Miscellaneous discharge measurements of canals in Yakima River drainage basin.*

| Date. | Stream. | Locality. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | | *Feet.* | *Sq. feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 13 | Fogarty canal | Yakima River, near Ellensburg. | | | | | 30 |
| October 6 | do | do | | | | | 53 |
| July 6 | Granger canal | Yakima River, near North Yakima. | | | | | 3.6 |
| August 21 | do | do | | | | | 2.6 |
| June 24 | Upper Scott canal | Left bank upper Naches Valley. | | 8.3 | 0.88 | | 7.3 |
| August 16 | do | do | | 6.7 | .55 | | 3.7 |
| September 4 | do | do | | 8.15 | .87 | | 7.1 |
| June 24 | Cox canal | Left bank Naches River. | | 2.71 | 1.31 | | 3.6 |
| June 21 | Kelly canal | Right bank Naches River. | | 1.0 | .80 | | .8 |
| | do | do | | 3.5 | .95 | | 3.2 |
| June 24 | Laswell canal | do | | 6.0 | .58 | | 3.5 |
| June 22 | Morrisey canal | Left bank Naches River, near North Yakima. | | | | | 4.0 |
| August 18 | do | do | | | | | 4.0 |
| September 1 | R. S. & C. Co.'s canal | At power house of power canal, near North Yakima. | | | | | 4.5 |
| November 6 | do | do | | | | | 8.5 |
| September 11 | Nelson canal | Left bank of Naches River, near North Yakima. | | | | | 7.4 |

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*Miscellaneous discharge measurements of canals in Yakima River drainage basin*—Contd.

| Date. | Stream. | Locality. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | | *Feet.* | *Sq. feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 7 | Union canal | Below power wasteway, in North Yakima. | | | | | 48 |
| September 15 | do | do | | | | | 10 |
| September 15 | Shanno Fruitvale canal. | Right bank Naches River, near North Yakima. | | 8.0 | 2.19 | | 17.5 |
| October 12 | do | do | | 4.0 | .70 | | 2.8 |
| September 14 | Wide hollow waste. | Near Yakima | | | | | 44 |
| June 9 | Prosser power flume. | Prosser | 12 | 118 | 2.09 | 22.90 | 246 |
| August 16 | do | do | 12 | 48 | 3.86 | 17.25 | 185 |
| September 1 | do | do | 12 | 71 | 1.48 | 19.58 | 105 |
| September 14 | do | do | 12 | 82 | 2.76 | 20.25 | 225 |
| September 1 | Taylor power flume. | do | 12 | 73 | .79 | | 58 |
| September 15 | do | do | 12 | 85 | .62 | | 53 |

## KACHESS LAKE NEAR EASTON, WASH.

In order to determine the amount of storage in Kachess Lake, which is controlled by a dam at its outlet, a record of the height of the water surface was kept from September 20 to December 31, 1905.

*Daily gage height, in feet, of Kachess Lake near Easton, Wash., for 1905.*

| Day. | Sept. | Oct. | Nov. | Dec. | Day. | Sept. | Oct. | Nov. | Dec. | Day. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0.1 | 0.95 | 0.45 | 12 | | 1.0 | 0.45 | 1.25 | 22 | 0.3 | 0.65 | 0.25 | 1.1 |
| 2 | | .25 | .85 | .45 | 13 | | 1.0 | .4 | 1.25 | 23 | .3 | .65 | .25 | 1.05 |
| 3 | | .6 | .8 | .45 | 14 | | .95 | .4 | 1.2 | 24 | .25 | .65 | .25 | 1.05 |
| 4 | | .8 | .8 | .4 | 15 | | .9 | .35 | 1.15 | 25 | .2 | 1.15 | .35 | 1.1 |
| 5 | | .85 | .8 | .4 | 16 | | .9 | .3 | 1.15 | 26 | .3 | 1.15 | .35 | 1.3 |
| 6 | | 1.0 | .7 | .4 | 17 | | .9 | .25 | 1.2 | 27 | .25 | 1.15 | .4 | 1.3 |
| 7 | | 1.2 | .6 | .4 | 18 | | .85 | .25 | 1.2 | 28 | .2 | 1.15 | .5 | 1.3 |
| 8 | | 1.1 | .6 | .4 | 19 | | .85 | .3 | 1.15 | 29 | .15 | 1.1 | .45 | 1.3 |
| 9 | | 1.1 | .5 | .3 | 20 | 0.4 | .75 | .45 | 1.15 | 30 | .15 | 1.2 | .45 | 1.3 |
| 10 | | 1.1 | .5 | 1.3 | 21 | .4 | .7 | .35 | 1.15 | 31 | | 1.15 | | 1.25 |
| 11 | | 1.0 | .45 | 1.3 | | | | | | | | | | |

## KACHESS RIVER NEAR EASTON, WASH.

This station was established October 14, 1903, by G. H. Bliss. It is located 2 miles northwest of Easton, Wash., and one-half mile below the foot of Lake Kachess, at the outlet of which a dam has been constructed by the Cascade Canal Company. This dam controls the flow.

The channel is straight for 600 feet above and 150 feet below the station. The current is swift. Both banks are high, wooded, and not liable to overflow. The bed of the stream is composed of gravel and rocks and is free from vegetation.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The cable has a span of 120 feet. The initial point for soundings is the south side of the aspen tree to which the cable is fastened on the left bank.

The gage is an inclined rod on the left bank directly under the cable. During 1905 the gage was read once each day by B. W. Morrow. The bench mark is the top of a large wire nail driven into the south side of the large aspen tree to which the cable is fastened on the

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left (north) bank. The tree is blazed and is marked "B. M." with black paint. The nail is near the base of the tree and has an elevation of 11.27 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 385–386; 135 p 90.
Discharge: 100, p 386; 135, p 90.
Discharge, monthly: 135, p 92.
Gage heights: 100, p 386; 135, p 91.
Rating table: 135, p 91.

*Discharge measurements of Kachess River near Easton, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second* | *Feet.* | *Second-feet.* |
| April 26 | W. J. Lightfoot | 74 | 189 | 2.86 | 5.10 | 540 |
| June 2 | do | 76 | 253 | 3.68 | 6.00 | 931 |
| June 27 | do | 70 | 121 | 2.18 | 4.10 | 263 |
| August 25 | W. C. Muldrow | 70 | 113 | 2.10 | 4.00 | 238 |
| November 16 | do | 71 | 102 | 1.53 | 3.72 | 156 |

*Daily gage height, in feet, of Kachess River near Easton, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.3 | 3.55 | 3.75 | 4.45 | 5.0 | 6.0 | 4.25 | 3.4 | 3.9 | 3.6 | 4.1 | 3.85 |
| 2 | 4.3 | 3.55 | 4.0 | 2.9 | 4.8 | 6.0 | 4.2 | 3.75 | 3.9 | 3.7 | 4.05 | 3.85 |
| 3 | 4.3 | 3.55 | 4.3 | 2.9 | 4.8 | 5.8 | 4.2 | 3.75 | 3.9 | 3.85 | 4.05 | 3.85 |
| 4 | 4.25 | 3.25 | 4.6 | 2.9 | 4.7 | 5.65 | 4.2 | 3.7 | 3.95 | 4.0 | 4.05 | 3.8 |
| 5 | 4.2 | 3.25 | 4.65 | 2.9 | 3.2 | 5.5 | 4.15 | 3.65 | 4.15 | 4.1 | 4.0 | 3.8 |
| 6 | 4.1 | 3.5 | 4.8 | 2.9 | 3.1 | 5.4 | 4.15 | 3.6 | 4.1 | 4.15 | 4.0 | 3.8 |
| 7 | 4.05 | 3.5 | 4.9 | 2.9 | 3.1 | 5.25 | 3.7 | 3.55 | 4.15 | 4.2 | 3.95 | 3.8 |
| 8 | 3.95 | 3.5 | 4.95 | 2.9 | 3.1 | 5.0 | 3.65 | 3.6 | 4.15 | 4.2 | 3.95 | 3.8 |
| 9 | 3.9 | 3.5 | 5.0 | 2.9 | 3.25 | 4.7 | 3.6 | 3.7 | 4.2 | 4.2 | 3.9 | 3.75 |
| 10 | 3.85 | 3.5 | 4.8 | 2.9 | 3.25 | 4.75 | 3.6 | 3.55 | 4.2 | 4.2 | 3.9 | 3.75 |
| 11 | 3.8 | 3.5 | 4.8 | 2.9 | 3.5 | 5.0 | 3.6 | 3.5 | 4.1 | 4.2 | 3.85 | 3.75 |
| 12 | 3.75 | 3.5 | 4.85 | 5.1 | 3.6 | 4.7 | 3.6 | 3.5 | 4.05 | 4.2 | 3.85 | 3.7 |
| 13 | 3.75 | 3.5 | 4.85 | 4.8 | 3.7 | 4.75 | 3.6 | 3.45 | 4.05 | 4.2 | 3.8 | 3.7 |
| 14 | 3.8 | 3.45 | 4.9 | 4.8 | 4.0 | 4.9 | 3.6 | 3.4 | 4.0 | 4.15 | 3.75 | 3.7 |
| 15 | 3.75 | 3.45 | 4.85 | 4.8 | 4.0 | 4.85 | 3.6 | 3.4 | 3.9 | 4.1 | 3.75 | 3.65 |
| 16 | 3.7 | 3.4 | 4.8 | 4.8 | 4.1 | 4.65 | 3.6 | 3.4 | 3.85 | 4.1 | 3.75 | 3.65 |
| 17 | 3.6 | 3.4 | 4.8 | 4.8 | 4.3 | 4.3 | 3.55 | 3.4 | 3.9 | 4.1 | 3.7 | 3.7 |
| 18 | 3.15 | 3.35 | 4.8 | 4.7 | 4.25 | 4.3 | 3.55 | 3.4 | 3.85 | 4.1 | 3.7 | 3.7 |
| 19 | 3.65 | 3.45 | 4.8 | 4.65 | 4.4 | 4.3 | 3.5 | 3.4 | 3.8 | 4.05 | 3.75 | 3.7 |
| 20 | 3.6 | 3.42 | 4.8 | 4.6 | 4.4 | 4.3 | 3.5 | 3.4 | 3.8 | 4.0 | 3.75 | 3.7 |
| 21 | 3.6 | 3.43 | 4.8 | 4.7 | 4.4 | 4.3 | 3.5 | 3.4 | 3.75 | 4.0 | 3.7 | 3.65 |
| 22 | 3.6 | 3.45 | 4.8 | 4.7 | 4.4 | 4.55 | 3.5 | 3.4 | 3.7 | 3.95 | 3.7 | 3.65 |
| 23 | 3.6 | 3.45 | 4.8 | 4.8 | 4.5 | 4.3 | 3.5 | 4.0 | 3.7 | 3.95 | 3.7 | 3.6 |
| 24 | 3.6 | 3.0 | 4.8 | 4.9 | 4.75 | 3.9 | 3.5 | 4.0 | 3.7 | 3.95 | 3.7 | 3.6 |
| 25 | 3.6 | 3.5 | 4.8 | 5.0 | 4.8 | 3.85 | 3.5 | 4.0 | 3.75 | 4.2 | 3.75 | 3.65 |
| 26 | 3.6 | 3.5 | 4.75 | 5.1 | 4.8 | 3.85 | 3.5 | 4.0 | 3.7 | 4.3 | 3.8 | 3.7 |
| 27 | 3.65 | 3.55 | 4.75 | 5.2 | 4.75 | 4.1 | 3.35 | 4.0 | 3.6 | 4.3 | 3.85 | 3.75 |
| 28 | 3.65 | 3.65 | 4.75 | 5.15 | 4.9 | 4.2 | 3.3 | 3.95 | 3.65 | 4.3 | 3.85 | 3.75 |
| 29 | 3.6 | ..... | 4.6 | 5.0 | 5.6 | 4.3 | 3.5 | 3.95 | 3.6 | 4.25 | 3.85 | 3.75 |
| 30 | 3.6 | ..... | 4.55 | 5.0 | 5.5 | 4.25 | 3.4 | 4.0 | 3.6 | 4.2 | 3.85 | 3.75 |
| 31 | 3.6 | ..... | 4.5 | 5.0 | 5.65 | ..... | 3.4 | 4.0 | ..... | 4.15 | ..... | 3.7 |

NOTE.—No ice record.

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*Station rating table for Kachess River near Easton, Wash., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.90 | 17 | 3.70 | 154 | 4.50 | 366 | 5.30 | 624 |
| 3.00 | 26 | 3.80 | 180 | 4.60 | 394 | 5.40 | 662 |
| 3.10 | 37 | 3.90 | 206 | 4.70 | 422 | 5.50 | 702 |
| 3.20 | 51 | 4.00 | 232 | 4.80 | 452 | 5.60 | 744 |
| 3.30 | 68 | 4.10 | 258 | 4.90 | 484 | 5.70 | 788 |
| 3.40 | 87 | 4.20 | 284 | 5.00 | 516 | 5.80 | 834 |
| 3.50 | 108 | 4.30 | 310 | 5.10 | 550 | 5.90 | 882 |
| 3.60 | 130 | 4.40 | 338 | 5.20 | 586 | 6.00 | 932 |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903–1905. It is well defined between gage heights 3.7 feet and 6 feet. Below 3.5 feet the table is uncertain.

*Estimated monthly discharge of Kachess River near Easton, Wash., for 1905.*

[Drainage area, 63 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 310 | 44 | 179 | 11,010 | 2.84 | 3.27 |
| February | 142 | 26 | 98.9 | 5,493 | 1.57 | 1.64 |
| March | 516 | 167 | 427 | 26,260 | 6.78 | 7.82 |
| April | 586 | 17 | 320 | 19,040 | 5.08 | 5.67 |
| May | 766 | 37 | 324 | 19,920 | 5.14 | 5.93 |
| June | 932 | 193 | 451 | 26,840 | 7.16 | 7.99 |
| July | 297 | 68 | 147 | 9,039 | 2.33 | 2.69 |
| August | 232 | 87 | 146 | 8,977 | 2.32 | 2.68 |
| September | 284 | 130 | 203 | 12,080 | 3.22 | 3.59 |
| October | 310 | 130 | 257 | 15,800 | 4.08 | 4.70 |
| November | 258 | 154 | 192 | 11,420 | 3.05 | 3.40 |
| December | 193 | 130 | 161 | 9,900 | 2.56 | 2.91 |
| The year | 932 | 17 | 242 | 175,800 | 3.84 | 52.29 |

## CLEALUM RIVER NEAR ROSLYN, WASH.

This station was established October 10, 1903, by G. H. Bliss. It is located 1,000 feet below the outlet of Lake Clealum. It is 2½ miles northwest of Roslyn and 6½ miles northwest of Clealum, Wash.

The channel is straight for 300 feet above and 900 feet below the station. The current is swift. Both banks are high, not liable to overflow, and heavily timbered. The bed of the stream is composed of gravel and is free from vegetation, and permanent.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is the south face of the pine tree, 18 inches in diameter, to which the cable is fastened on the left bank.

The original gage was an inclined rod on the left bank 20 feet upstream from the cable. It was injured by flood, and August 28, 1905, was replaced by a similar gage with the datum 0.56 foot higher. All gage heights for 1905 have been reduced to the datum of the old gage. During 1905 the gage was read once each day by Charles M. Davis and E. F. Dunkin. The bench mark is a large spike driven into a root on the downstream side of the blazed tree, to which the cable is fastened, on the left bank; elevation, 17.40 feet above the zero of the gage.

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Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 384–385; 135, pp 92–93.
Discharge: 100, p 385; 135, p 93.
Discharge, monthly: 135, p 95.
Gage heights: 100, p 385; 135, pp 93–94.
Rating table: 135, p 94.

*Discharge measurements of Cleallum River near Roslyn, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 28 | W. J. Lightfoot | 134 | 1,009 | 1.94 | 4.85 | 1,963 |
| June 1 | do | 148 | 1,187 | 2.68 | 6.00 | 3,182 |
| July 20 | do | 125 | 748 | .88 | 2.52 | 659 |
| August 26 | W. C. Muldrow | 121 | 653 | .62 | 2.06 | 408 |
| September 19 | do | 75 | 127 | 2.11 | 1.62 | 268 |
| November 15 | do | 120 | 673 | .52 | 2.13 | 344 |

*Daily gage height, in feet, of Cleallum River near Roslyn, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.0 | 1.4 | 2.5 | 2.4 | 4.0 | 5.9 | 3.6 | 2.45 | 1.8 | 2.15 | 2.75 | 2.15 |
| 2 | 2.05 | 1.35 | 2.8 | 2.3 | 3.7 | 5.9 | 3.6 | 2.4 | 1.75 | 2.18 | 2.65 | 2.15 |
| 3 | 2.05 | 1.35 | 3.4 | 2.2 | 3.6 | 5.7 | 3.6 | 2.35 | 1.70 | 2.65 | 2.55 | 2.1 |
| 4 | 2.0 | 1.4 | 4.05 | 1.85 | 3.5 | 5.9 | 3.5 | 2.3 | 1.7 | 4.45 | 2.5 | 2.05 |
| 5 | 1.95 | 1.4 | 4.4 | 1.75 | 3.5 | 5.5 | 3.4 | 2.3 | 1.65 | 4.46 | 2.45 | 2.05 |
| 6 | 1.85 | 1.35 | 4.4 | 1.7 | 3.8 | 5.1 | 3.35 | 2.2 | 1.65 | 4.5 | 2.35 | 2.1 |
| 7 | 1.8 | 1.35 | 4.25 | 1.6 | 4.1 | 5.0 | 3.25 | 2.15 | 1.65 | 4.3 | 2.35 | 2.1 |
| 8 | 1.75 | 1.4 | 4.2 | 1.55 | 4.7 | 5.0 | 3.15 | 2.15 | 1.6 | 4.0 | 2.3 | 2.0 |
| 9 | 1.7 | 1.4 | 4.25 | 1.6 | 5.3 | 5.3 | 3.1 | 2.15 | 1.65 | 3.65 | 2.25 | 1.95 |
| 10 | 1.6 | 1.35 | 4.2 | 1.7 | 5.0 | 5.5 | 3.1 | 2.1 | 1.65 | 3.44 | 2.2 | 1.95 |
| 11 | 1.5 | 1.3 | 4.3 | 1.8 | 4.8 | 5.5 | 3.1 | 2.15 | 1.65 | 3.2 | 2.15 | 1.9 |
| 12 | 1.5 | 1.3 | 4.4 | 2.2 | 4.2 | 5.3 | 3.0 | 2.1 | ..... | 3.06 | 2.15 | 1.85 |
| 13 | 1.45 | 1.25 | 4.4 | 2.9 | 4.1 | 5.0 | 2.9 | 2.1 | ..... | 2.85 | 2.05 | 1.85 |
| 14 | 1.4 | 1.2 | 4.1 | 3.0 | 4.2 | 4.7 | 2.85 | 2.05 | ..... | 2.8 | 2.05 | 1.8 |
| 15 | 1.5 | 1.2 | 3.9 | 3.1 | 4.4 | 4.2 | 2.7 | 2.05 | 1.65 | 2.75 | 2.05 | 1.8 |
| 16 | 1.5 | 1.15 | 3.8 | 3.3 | 4.3 | 4.1 | 2.6 | 2.0 | ..... | 2.65 | 2.00 | 1.75 |
| 17 | 1.55 | 1.15 | 3.7 | 3.2 | 4.3 | 4.0 | 2.6 | 2.05 | ..... | 2.65 | 1.95 | 1.8 |
| 18 | 1.5 | 1.1 | 3.85 | 3.1 | 4.2 | 4.0 | 2.6 | 2.3 | 1.6 | 2.55 | 1.95 | 1.8 |
| 19 | 1.45 | 1.15 | 4.0 | 3.25 | 4.1 | 4.0 | 2.6 | 2.3 | 1.6 | 2.5 | 1.9 | 1.75 |
| 20 | 1.4 | 1.2 | 4.0 | 3.4 | 3.9 | 4.0 | 2.5 | 2.25 | 1.65 | 2.45 | 2.05 | 1.75 |
| 21 | 1.4 | 1.2 | 4.0 | 3.8 | 3.8 | 4.1 | 2.5 | 2.2 | 1.68 | 2.35 | 2.05 | 1.75 |
| 22 | 1.45 | 1.2 | 3.95 | 4.1 | 3.6 | 4.1 | 2.6 | 2.1 | 1.73 | 2.3 | 2.0 | 1.75 |
| 23 | 1.4 | 1.25 | 3.9 | 4.6 | 3.6 | 4.1 | 2.6 | 2.25 | 1.75 | 2.25 | 2.0 | 1.7 |
| 24 | 1.45 | 1.35 | 3.75 | 4.7 | 3.5 | 3.9 | 2.7 | 2.2 | 1.78 | 2.3 | 1.95 | 1.7 |
| 25 | 1.4 | 1.5 | 3.3 | 5.6 | 3.4 | 3.9 | 2.6 | 2.1 | 1.82 | 3.55 | 1.95 | 1.7 |
| 26 | 1.4 | 1.8 | 3.1 | 4.8 | 3.4 | 3.8 | 2.6 | 2.0 | 1.86 | 4.25 | 2.05 | 1.75 |
| 27 | 1.45 | 2.05 | 2.9 | 5.65 | 3.8 | 3.7 | 2.6 | 1.95 | 2.05 | 4.05 | 2.15 | 1.85 |
| 28 | 1.5 | 2.25 | 2.7 | 5.3 | 4.3 | 4.0 | 2.6 | 1.9 | 2.15 | 3.65 | 2.15 | 1.8 |
| 29 | 1.5 | ..... | 2.6 | 4.7 | 4.9 | 3.8 | 2.6 | 1.9 | 2.18 | 3.4 | 2.15 | 1.8 |
| 30 | 1.45 | ..... | 2.4 | ..... | 5.0 | 3.65 | 2.52 | 1.85 | 2.18 | 3.1 | 2.15 | 1.75 |
| 31 | 1.4 | ..... | 2.3 | ..... | 5.4 | ..... | 2.45 | 1.8 | ..... | 2.9 | ..... | 1.75 |

NOTE.—No ice record.

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*Station rating table for Clealum River near Roslyn, Wash., from October 10, 1903, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.10 | 140 | 2.40 | 530 | 3.70 | 1,130 | 5.00 | 2,100 |
| 1.20 | 165 | 2.50 | 565 | 3.80 | 1,185 | 5.10 | 2,190 |
| 1.30 | 190 | 2.60 | 605 | 3.90 | 1,245 | 5.20 | 2,290 |
| 1.40 | 215 | 2.70 | 645 | 4.00 | 1,310 | 5.30 | 2,390 |
| 1.50 | 240 | 2.80 | 685 | 4.10 | 1,380 | 5.40 | 2,490 |
| 1.60 | 270 | 2.90 | 725 | 4.20 | 1,450 | 5.50 | 2,590 |
| 1.70 | 300 | 3.00 | 770 | 4.30 | 1,520 | 5.60 | 2,690 |
| 1.80 | 330 | 3.10 | 815 | 4.40 | 1,590 | 5.70 | 2,790 |
| 1.90 | 360 | 3.20 | 865 | 4.50 | 1,670 | 5.80 | 2,890 |
| 2.00 | 390 | 3.30 | 915 | 4.60 | 1,750 | 5.90 | 2,990 |
| 2.10 | 425 | 3.40 | 965 | 4.70 | 1,830 | 6.00 | 3,100 |
| 2.20 | 460 | 3.50 | 1,020 | 4.80 | 1,920 | | |
| 2.30 | 495 | 3.60 | 1,075 | 4.90 | 2,010 | | |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903–1905. It is well defined.

*Estimated monthly discharge of Clealum River near Roslyn, Wash., for 1905.*

[Drainage area, 205 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January [a] | 408 | 215 | 269 | 16,540 | 1.31 | 1.51 |
| February [a] | 478 | 140 | 211 | 11,720 | 1.03 | 1.07 |
| March | 1,590 | 495 | 1,155 | 71,020 | 5.63 | 6.49 |
| April | 2,740 | 255 | 1,012 | 60,220 | 4.94 | 5.51 |
| May | 2,490 | 965 | 1,450 | 89,160 | 7.07 | 8.15 |
| June | 2,990 | 1,102 | 1,841 | 109,600 | 8.98 | 10.02 |
| July | 1,075 | 548 | 733 | 45,070 | 3.58 | 4.13 |
| August | 548 | 330 | 438 | 26,930 | 2.14 | 2.47 |
| September [b] | 453 | 270 | 314 | 18,680 | 1.53 | 1.71 |
| October | 1,670 | 442 | 887 | 54,540 | 4.33 | 4.99 |
| November | 665 | 360 | 452 | 26,900 | 2.20 | 2.46 |
| December | 442 | 300 | 352 | 21,640 | 1.72 | 1.98 |
| The year | 2,990 | 140 | 760 | 552,000 | 3.70 | 50.49 |

[a] Estimates unreliable owing to probable ice conditions.
[b] Missing gage heights interpolated.

NOTE.—Low-water gage heights prior to August 28 are uncertain.

## NACHES RIVER NEAR NILE, WASH.

This station was established June 23, 1904, by G. F. Harley. It is located 1¾ miles above the highway bridge, 23 miles northwest of North Yakima, and 8 miles southeast of Nile, Wash. The station is 1¾ miles above the junction of Naches and Tieton rivers. The channel is straight for about 600 feet above and 300 feet below the station. The current is moderate at the station and swift above and below. The right bank is low, wooded, and overflows only during extreme high floods. The left bank is high, rocky, clean, and not liable to overflow. The bed of the stream is composed of clean gravel and cobbles and

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is permanent. There is one channel at all except very high stages, when there are two. The section is flat and shallow.

Discharge measurements are made by means of a cable, car, and tagged wire. The cable has a span of 216 feet. The initial point for soundings is the south face of the pine on the north bank to which the cable is fastened.

An inclined staff gage is fastened to timbers buried on the left bank. During 1905 the gage was read once each day by W. H. Johnson. Bench marks were established as follows: (1) A point on the ledge 25 feet upstream from the tree supporting the cable on the north bank, marked with a cross and "B. M.;" elevation, 9.85 feet above the zero of the gage. (2) A large spike in the base of a 30-inch pine tree, 115 feet upstream from the north cable support; elevation, 8.76 feet above the zero of the gage. (3) A United States Geological Survey standard bronze tablet set in a bowlder 700 feet east of north cable support, 300 feet from the river, marked on the tablet "1661;" elevation, 1,660.824 feet above sea level and 9.20 feet above the zero of the gage.

A description of this station, with gage heights, discharge data, and rating table, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 95–97.

*Discharge measurements of Naches River near Nile, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 20 | W. J. Lightfoot | 190 | 450 | 4.76 | 5.00 | 2,141 |
| September 5 | W. C. Muldrow | 140 | 228 | 1.41 | 3.50 | 321 |
| October 11 | do | 190 | 318 | 2.90 | 4.25 | 921 |
| October 30 | do | 187 | 259 | 2.37 | 4.00 | 615 |
| November 20 | do | 142 | 218 | 2.07 | 3.82 | 449 |

*Daily gage height, in feet, of Naches River near Nile, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.9 | 3.6 | 4.4 | 4.4 | 4.9 | 5.6 | 4.8 | 4.0 | 3.6 | 3.6 | 3.9 | 3.75 |
| 2 | 4.0 | 3.7 | 4.7 | 4.3 | 4.8 | 5.5 | 4.7 | 3.9 | 3.6 | 3.7 | 3.9 | 3.7 |
| 3 | 4.0 | 3.6 | 5.1 | 4.3 | 4.8 | 5.9 | 4.7 | 3.9 | 3.6 | 3.8 | 3.9 | 3.7 |
| 4 | 4.0 | 3.6 | 5.2 | 4.3 | 4.7 | 6.1 | 4.6 | 3.9 | 3.6 | 4.3 | 3.9 | 3.7 |
| 5 | 3.9 | 3.7 | 5.3 | 4.3 | 4.6 | 5.8 | 4.6 | 3.8 | 3.6 | 4.3 | 4.0 | 3.7 |
| 6 | 3.9 | 3.6 | 5.2 | 4.4 | 4.7 | 5.6 | 4.5 | 3.8 | 3.6 | 4.7 | 3.9 | 3.75 |
| 7 | 3.9 | 3.7 | 5.2 | 4.5 | 4.8 | 5.5 | 4.5 | 3.8 | 3.5 | 4.8 | 3.8 | 3.8 |
| 8 | 3.8 | 3.6 | 5.1 | 4.5 | 5.0 | 5.4 | 4.4 | 3.8 | 3.5 | 4.6 | 3.8 | 3.8 |
| 9 | 3.8 | 3.7 | 5.3 | 4.6 | 5.3 | 5.5 | 4.4 | 3.8 | 3.5 | 4.4 | 3.8 | 3.7 |
| 10 | 3.6 | 3.5 | 5.4 | 4.5 | 5.1 | 5.6 | 4.4 | 3.8 | 3.5 | 4.3 | 3.8 | 3.7 |
| 11 | 3.6 | 3.5 | 5.4 | 4.5 | 4.9 | 5.5 | 4.3 | 3.7 | 3.5 | 4.2 | 3.8 | 3.65 |
| 12 | 3.7 | 3.4 | 5.3 | 4.6 | 4.8 | 5.5 | 4.2 | 3.7 | 3.5 | 4.2 | 3.7 | 3.8 |
| 13 | 3.8 | 3.4 | 5.1 | 4.6 | 4.8 | 5.4 | 4.2 | 3.7 | 3.6 | 4.1 | 3.7 | 3.75 |
| 14 | 3.8 | 3.3 | 5.0 | 4.6 | 4.9 | 5.2 | 4.1 | 3.7 | 3.6 | 4.1 | 3.7 | 3.9 |
| 15 | 3.9 | 3.3 | 4.9 | 4.5 | 4.9 | 5.1 | 4.1 | 3.7 | 3.6 | 4.1 | 3.7 | 3.85 |
| 16 | 4.0 | 3.4 | 5.0 | 4.6 | 4.9 | 5.0 | 4.1 | 3.7 | 3.5 | 4.0 | 3.7 | 3.8 |
| 17 | 3.8 | 3.4 | 5.1 | 4.5 | 5.0 | 4.9 | 4.0 | 3.8 | 3.5 | 4.0 | 3.7 | 3.75 |
| 18 | 3.8 | 3.5 | 5.2 | 4.6 | 4.9 | 4.9 | 4.0 | 3.8 | 3.6 | 4.0 | 3.7 | 3.8 |
| 19 | 3.9 | 3.7 | 5.1 | 4.6 | 4.9 | 4.8 | 3.9 | 3.7 | 3.6 | 3.9 | 3.8 | 3.7 |
| 20 | 3.8 | 3.7 | 5.1 | 4.8 | 4.8 | 4.8 | 3.9 | 3.7 | 3.5 | 3.9 | 3.9 | 3.8 |
| 21 | 3.6 | 3.8 | 5.0 | 4.9 | 4.7 | 4.8 | 4.0 | 3.7 | 3.6 | 3.9 | 3.85 | 3.7 |
| 22 | 3.6 | 3.7 | 4.9 | 4.9 | 4.7 | 4.9 | 3.9 | 3.7 | 3.6 | 3.9 | 3.8 | 3.7 |
| 23 | 3.6 | 3.8 | 4.9 | 5.0 | 4.6 | 4.8 | 4.0 | 3.7 | 3.5 | 3.9 | 3.8 | 3.6 |

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*Daily gage height, in feet, of Naches River near Nile, Wash., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 3.7 | 3.8 | 4.8 | 5.3 | 4.6 | 4.7 | 4.0 | 3.6 | 3.5 | 3.9 | 3.8 | 3.6 |
| 25 | 3.6 | 3.9 | 4.8 | 5.6 | 4.6 | 4.8 | 4.0 | 3.6 | 3.5 | 4.1 | 3.75 | 3.8 |
| 26 | 3.6 | 4.1 | 4.7 | 5.7 | 4.5 | 4.7 | 3.9 | 3.6 | 3.6 | 4.2 | 3.8 | 3.8 |
| 27 | 3.6 | 4.1 | 4.6 | 5.6 | 4.7 | 4.9 | 3.9 | 3.6 | 3.7 | 4.2 | 3.85 | 3.7 |
| 28 | 3.8 | 4.2 | 4.6 | 5.4 | 4.9 | 5.0 | 4.0 | 3.7 | 3.7 | 4.1 | 3.8 | 3.8 |
| 29 | 3.8 | ..... | 4.5 | 5.2 | 5.0 | 4.8 | 3.9 | 3.7 | 3.7 | 4.1 | 3.8 | 3.75 |
| 30 | 3.7 | ..... | 4.4 | 5.0 | 5.1 | 4.7 | 3.9 | 3.7 | 3.7 | 4.0 | 3.8 | 3.7 |
| 31 | 3.6 | ..... | 4.4 | ..... | 5.3 | ..... | 3.9 | 3.6 | ..... | 4.0 | ..... | 3.8 |

NOTE.—No ice record.

*Station rating table for Naches River near Nile, Wash., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.20 | 160 | 4.00 | 630 | 4.80 | 1,690 | 5.60 | 3,130 |
| 3.30 | 195 | 4.10 | 730 | 4.90 | 1,850 | 5.70 | 3,350 |
| 3.40 | 235 | 4.20 | 840 | 5.00 | 2,020 | 5.80 | 3,570 |
| 3.50 | 280 | 4.30 | 960 | 5.10 | 2,190 | 5.90 | 3,810 |
| 3.60 | 330 | 4.40 | 1,090 | 5.20 | 2,370 | 6.00 | 4,050 |
| 3.70 | 390 | 4.50 | 1,230 | 5.30 | 2,550 | 6.10 | 4,310 |
| 3.80 | 460 | 4.60 | 1,380 | 5.40 | 2,740 | 6.20 | 4,570 |
| 3.90 | 540 | 4.70 | 1,530 | 5.50 | 2,930 | | |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904–5. It is fairly well defined between gage heights 3.8 feet and 5 feet.

*Estimated monthly discharge of Naches River near Nile, Wash., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 630 | 330 | 453 | 27,850 |
| February | 840 | 195 | 385 | 21,380 |
| March | 2,740 | 1,090 | 1,970 | 121,100 |
| April | 3,350 | 960 | 1,659 | 98,720 |
| May | 2,550 | 1,230 | 1,770 | 108,800 |
| June | 4,310 | 1,530 | 2,398 | 142,700 |
| July | 1,690 | 540 | 865 | 53,190 |
| August | 630 | 330 | 421 | 25,890 |
| September | 390 | 280 | 318 | 18,920 |
| October | 1,690 | 330 | 770 | 47,350 |
| November | 630 | 390 | 467 | 27,740 |
| December | 540 | 330 | 422 | 25,950 |
| The year | 4,310 | 195 | 992 | 719,600 |

## NACHES RIVER BELOW MOUTH OF TIETON RIVER, WASHINGTON.

This station was established August 4, 1905, for low-water observations. It was discontinued October 28, 1905. It is located about 500 feet below the mouth of Tieton River and 1,500 feet above the intake of Wapatox canal, near North Yakima, Wash.

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The channel is straight for 500 feet above and below the station. The current is swift. Both banks are low and liable to overflow. The right bank is clean; the left wooded. The bed of the stream is composed of gravel and is permanent. There is but one channel at all stages.

Discharge measurements are made by means of a meter suspended from a light cable and operated from the bank. The initial point for soundings is a nail in the stump on the left bank to which the cable is fastened.

A vertical staff gage is spiked to a stump on the left bank. During 1905 the gage was read once each day by F. M. Johnson. The bench mark is a spike in the root of a stump 40 feet north of the initial point for soundings; elevation, 7.33 feet above the datum of the gage.

*Discharge measurements of Naches River below mouth of Tieton River, Washington, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 4 | W. J. Lightfoot | 116 | 361 | 2.13 | 3.3 | 769 |
| September 5 | W. C. Muldrow | 104 | 313 | 1.37 | 2.8 | 431 |
| October 11 | do | 119 | 433 | 2.45 | 3.8 | 1,061 |

*Daily gage height, in feet, of Naches River below mouth of Tieton River, Washington, for 1905.*

| Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. | Day. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 2.7 | 2.8 | 12 | 3.3 | 2.8 | 3.7 | 22 | 3.1 | 3.0 | 3.1 |
| 2 | ..... | 2.7 | 2.8 | 13 | 3.3 | 3.0 | 3.7 | 23 | 3.0 | 3.0 | 3.1 |
| 3 | ..... | 2.8 | 3.3 | 14 | 3.2 | 2.9 | 3.6 | 24 | 3.0 | 2.9 | 3.1 |
| 4 | 3.3 | 2.8 | 4.8 | 15 | 3.8 | 2.8 | 3.5 | 25 | 3.0 | 2.8 | 4.9 |
| 5 | 3.3 | 2.9 | 4.7 | 16 | 2.9 | 2.7 | 3.5 | 26 | 2.9 | 2.9 | 3.9 |
| 6 | 3.3 | 2.8 | 4.7 | 17 | 3.2 | 2.8 | 3.4 | 27 | 2.9 | 3.1 | 3.7 |
| 7 | 3.3 | 2.8 | 4.7 | 18 | 3.2 | 2.7 | 3.4 | 28 | 3.0 | 3.0 | 3.6 |
| 8 | 3.3 | 2.8 | 4.4 | 19 | 3.3 | 2.8 | 3.4 | 29 | 2.9 | 2.9 | ..... |
| 9 | 3.3 | 2.8 | 4.1 | 20 | 3.3 | 2.8 | 3.2 | 30 | 2.9 | 2.8 | ..... |
| 10 | 3.3 | 2.8 | 3.8 | 21 | 3.3 | 2.9 | 3.2 | 31 | 2.8 | ..... | ..... |
| 11 | 3.3 | 2.9 | 3.8 | | | | | | | | |

*Station rating table for Naches River below mouth of Tieton River, Washington, from August 4 to October 28, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.50 | 300 | 3.20 | 655 | 3.90 | 1,165 | 4.50 | 1,670 |
| 2.60 | 340 | 3.30 | 720 | 4.00 | 1,245 | 4.60 | 1,760 |
| 2.70 | 385 | 3.40 | 790 | 4.10 | 1,325 | 4.70 | 1,850 |
| 2.80 | 435 | 3.50 | 860 | 4.20 | 1,410 | 4.80 | 1,940 |
| 2.90 | 485 | 3.60 | 935 | 4.30 | 1,495 | 4.90 | 2,035 |
| 3.00 | 540 | 3.70 | 1,010 | 4.40 | 1,580 | 5.00 | 2,130 |
| 3.10 | 595 | 3.80 | 1,085 | | | | |

The above table is applicable only for open-channel conditions. It is based on three discharge measurements made during 1905. It is not well defined.

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*Estimated monthly discharge of Naches River below mouth of Tieton River, Washington, for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| August 4–31 | 1,085 | 435 | 608 | 33,770 |
| September | 595 | 385 | 459 | 27,310 |
| October 1–28 | 2,035 | 435 | 1,051 | 58,370 |

## NACHES RIVER NEAR NORTH YAKIMA, WASH.

Naches River has its source in the Cascade Mountains, Yakima County, Wash., and flows southeastward, entering Yakima River a short distance above North Yakima. Its principal tributaries are Tieton River, Cowiche, Rattlesnake, and Nile creeks, and Bumping River. The flow of the latter has already been increased by American River when it joins the Naches. Below the Tieton, almost to the point where it enters the Yakima, the Naches flows over flat bars of gravel in numerous, crooked, and constantly changing channels. These gravel bars are in some instances one-half mile in width.

Naches River is important, because of its rapid fall and the ease with which it can be used for irrigation purposes. Naches Valley, through which it flows, is already extensively irrigated from it. It is also the source of domestic water supply for the town of North Yakima and of water supply and power for the Northwestern Light and Water Company.

The original station on Naches River was established August 14, 1893, by F. H. Newell, at a point a few hundred yards above the mouth of the river, near the bridge of the Northern Pacific Railway.

The flood of November, 1896, modified the channel very greatly. On account of the instability of the channel the station was abandoned in February, 1897, though a number of discharge measurements were made during the season.

May 19, 1897, a station was established on Yakima River 5 miles above the mouth of the Naches, at the Northern Pacific Railway bridge near Selah, Wash., with the idea that the difference in discharge between this station and the one at Union Gap would give approximately the discharge of Naches River. Two ditches, located in Moxee Valley, took water out of the river between these two points, but their combined flow was about counterbalanced by that received from Atanum Creek and the Wide Hollow wastage at Old Town.

The station on Naches River was reestablished February 1, 1898, and the station at Selah, on Yakima River, was discontinued. Since the reestablishment of the Naches station the river channel has been in a condition more favorable for meter observations than formerly. September 21, 1903, the station was moved to a location between the railroad and highway bridge.

The channel is straight for 100 feet above and for 75 feet below the cable. The current is swift. Both banks are low and covered with gravel. At flood stages the rock-filled crib will prevent overflow on both banks. The bed of the stream is composed of gravel, is free from vegetation, and is somewhat shifting.

Discharge measurements are made by means of a cable, car, tagged wire, and a stay wire, 180 feet above the Northern Pacific Railway bridge and 170 feet below the highway bridge, at which discharge measurements were formerly made. The cable has a total span of 280 feet. The initial point for soundings is the south face of the cottonwood tree on the north bank, to which the cable is fastened.

The present gage, known as No. 5, is on the left bank of the river, 30 feet downstream from the railroad bridge. The lower section of the rod is inclined at an angle of 36° 30′ with the horizontal. The upper section is inclined at an angle of 80° with the horizontal.

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During 1905 gage heights were observed once each day by Patrick Gallagher. This gage is referred to bench marks as follows: (1) A United States Geological Survey copper plug marked "1090 T;" elevation, 1,089.96 feet above sea level and 19.74 feet above the zero of the gage. It is located in the center of the west end of the most southerly stone pier of the railroad bridge. The elevation of the zero of the gage is 1,070.034 feet above sea level. (2) A cross in the top of the center of the downstream end of the railroad-bridge pier on the right bank. Its elevation above the zero of the gage is 19.94 feet and above sea level is 1,089.98 feet. (3) A railroad spike driven into the south side of the telegraph pole 23 feet north of the gage and 21 feet east of the railroad track. Its elevation is 17.81 feet above the zero of the gage.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; Bull=Bulletin; WS=Water-Supply Paper):

Description: Ann 14, ii, p 133; 18, iv, p 355; Bull 131, pp 73–74; 140, pp 244–245; WS 16, p 174; 28, p 158; 38, pp 372–373; 51, p 440; 66, p 133; 85, pp 191–192; 100, pp 379–380; 135, p 98.

Discharge: Ann 14, ii, p 133; 18, iv, p 355; Bull 131, pp 74, 90; 140, p 245; WS 16, p 174; 38, p 373; 51, p 440; 66, p 134; 85, p 192; 100, p 380; 135, p 101.

Discharge, monthly: Ann 18, iv, p 356; 20, iv, pp 499, 503; 21, iv, p 426; 22, iv, p 445; WS 75, p 202; 85, p 194; 100, p 382; 135, p 102.

Discharge, yearly: Ann 20, iv, p 62.

Gage heights: Bull 131, p 74; 140, p 245; WS 11, p 84; 16, p 174; 28, p 164; 38, p 373; 51, p 440; 66, p 134; 85, p 193; 100, p 381; 135, p 101.

Hydrographs: Ann 20, iv, p 503; 21, iv, p 426; 22, iv, p 446.

Rainfall and run-off relation: Ann 20, iv, p 500.

Rating tables: Ann 18, iv, p 356; WS 39, p 454; 52, p 522; 66, p 177; 85, p 193; 100, p 381; 135, p 102.

*Discharge measurements of Naches River near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| September 8 | W. C. Muldrow | 112 | 111 | 0.90 | 3.60 | 99 |
| September 23 | do | 130 | 194 | 1.37 | 4.12 | 266 |
| November 3 | do | 121 | 255 | 2.06 | 4.70 | 522 |
| November 17 | do | 121 | 241 | 1.47 | 4.32 | 355 |

*Daily gage height, in feet, of Naches River near North Yakima, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 4.6 | 5.8 | 5.6 | 6.2 | 6.9 | 6.3 | 4.6 | 3.5 | ..... | 4.8 | 4.4 |
| 2 | 5.2 | 4.6 | 6.2 | ..... | 6.1 | 6.9 | ..... | 4.5 | 3.5 | 4.1 | 4.8 | 4.4 |
| 3 | 5.2 | 4.6 | 6.8 | 5.0 | 6.0 | 7.1 | 6.1 | 4.6 | 3.6 | 4.8 | 4.7 | ..... |
| 4 | 5.2 | 4.6 | 6.8 | 5.0 | 5.8 | ..... | 6.0 | 4.7 | 3.6 | 5.1 | 4.7 | 4.4 |
| 5 | 5.1 | ..... | ..... | 5.0 | 5.8 | 7.5 | 5.8 | 4.5 | 3.6 | 5.2 | ..... | 4.4 |
| 6 | 5.1 | 4.6 | 6.8 | 5.6 | 5.8 | 7.2 | 5.7 | 4.45 | 3.7 | 5.6 | 4.7 | 4.4 |
| 7 | 5.0 | 4.6 | 6.8 | 5.6 | ..... | 7.1 | 5.6 | 4.4 | 3.6 | 6.1 | 4.7 | 4.4 |
| 8 | ..... | 4.6 | 6.8 | 5.7 | 6.2 | 7.0 | 5.6 | 4.3 | 3.6 | ..... | 4.6 | 4.4 |
| 9 | 4.9 | 4.6 | 6.8 | ..... | 6.3 | 7.1 | 5.6 | 4.3 | 3.6 | 5.6 | 4.6 | 4.4 |
| 10 | 4.8 | 4.6 | 6.9 | 5.7 | 6.4 | 7.2 | 5.6 | 4.2 | 3.6 | 5.4 | 4.5 | ..... |
| 11 | 4.7 | 4.6 | 6.9 | 5.7 | 6.2 | ..... | 5.5 | 4.2 | 3.6 | 5.3 | 4.5 | 4.1 |
| 12 | 4.7 | ..... | ..... | 5.7 | 6.1 | 7.2 | 5.4 | 4.2 | 3.7 | 5.2 | ..... | 4.1 |
| 13 | 4.6 | 4.5 | 6.8 | 5.7 | 6.0 | 7.0 | 5.3 | 4.1 | 3.8 | 5.1 | 4.5 | 4.1 |
| 14 | 4.6 | 4.5 | 6.7 | 5.7 | ..... | 6.8 | 5.1 | 4.0 | 4.0 | 5.0 | 4.4 | 4.6 |
| 15 | ..... | 4.5 | 6.5 | 5.7 | 6.2 | 6.7 | 5.0 | 4.0 | 3.9 | ..... | 4.4 | 4.3 |
| 16 | 4.8 | 4.4 | 6.5 | ..... | 6.2 | 6.6 | 5.0 | 4.0 | 3.8 | 4.9 | 4.4 | 4.3 |
| 17 | 4.8 | 4.4 | 6.5 | 5.6 | 6.2 | 6.5 | 5.0 | 3.9 | ..... | 4.9 | 4.3 | ..... |
| 18 | 4.7 | 4.4 | 6.6 | 5.6 | 6.2 | ..... | 4.9 | 3.9 | 3.8 | 4.8 | 4.3 | 4.3 |
| 19 | 4.7 | ..... | ..... | 5.6 | 6.1 | 6.3 | 4.9 | 4.4 | 3.8 | 4.8 | ..... | 4.4 |

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*Daily gage height, in feet, of Naches River near North Yakima, Wash., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 4.6 | 4.6 | 6.5 | 5.7 | 6.1 | 6.3 | 4.9 | ..... | 3.8 | 4.8 | 4.5 | 4.4 |
| 21 | 4.6 | 4.6 | 6.5 | 5.9 | 6.05 | 6.3 | 4.9 | 4.1 | 4.0 | 4.7 | 4.5 | 4.3 |
| 22 | ..... | 4.6 | 6.4 | 6.0 | 6.0 | 6.3 | 5.0 | 3.9 | 4.1 | ..... | 4.4 | 4.3 |
| 23 | 4.6 | 4.8 | 6.3 | ..... | 5.9 | 6.2 | 5.0 | 3.9 | 4.1 | 4.7 | 4.4 | 4.3 |
| 24 | 4.6 | 5.0 | 6.3 | 6.4 | 5.8 | 6.2 | 5.0 | 3.8 | ..... | 4.6 | 4.4 | ..... |
| 25 | 4.6 | 5.1 | 6.2 | 6.8 | 5.7 | ..... | 4.9 | 3.7 | 4.1 | 5.0 | 4.4 | 4.3 |
| 26 | 4.6 | ..... | ..... | 7.0 | 5.7 | 6.2 | 4.8 | 3.7 | 4.1 | 5.3 | ..... | 4.4 |
| 27 | 4.6 | 5.5 | 6.1 | 6.9 | 5.8 | 6.2 | 4.7 | ..... | 4.4 | 5.2 | 4.4 | 4.4 |
| 28 | 4.6 | 5.6 | 6.0 | 6.7 | ..... | 6.5 | 4.7 | 3.6 | 4.3 | 5.1 | 4.4 | 4.3 |
| 29 | ..... | ..... | 5.9 | 6.5 | 6.1 | 6.3 | 4.7 | 3.6 | 4.2 | ..... | 4.4 | 4.3 |
| 30 | 4.6 | ..... | 5.8 | ..... | 6.4 | 6.3 | 4.65 | 3.6 | 4.0 | 4.9 | 4.4 | 4.3 |
| 31 | 4.6 | ..... | 5.7 | ..... | 6.7 | ..... | 4.6 | 3.5 | ..... | 4.8 | ..... | ..... |

*Station rating table for Naches River near North Yakima, Wash., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.50 | 100 | 4.60 | 478 | 5.60 | 1,098 | 6.60 | 2,128 |
| 3.60 | 118 | 4.70 | 530 | 5.70 | 1,174 | 6.70 | 2,255 |
| 3.70 | 139 | 4.80 | 584 | 5.80 | 1,253 | 6.80 | 2,384 |
| 3.80 | 163 | 4.90 | 640 | 5.90 | 1,339 | 6.90 | 2,515 |
| 3.90 | 190 | 5.00 | 698 | 6.00 | 1,433 | 7.00 | 2,648 |
| 4.00 | 220 | 5.10 | 758 | 6.10 | 1,535 | 7.10 | 2,785 |
| 4.10 | 254 | 5.20 | 820 | 6.20 | 1,645 | 7.20 | 2,926 |
| 4.20 | 292 | 5.30 | 884 | 6.30 | 1,762 | 7.30 | 3,071 |
| 4.30 | 334 | 5.40 | 952 | 6.40 | 1,882 | 7.40 | 3,220 |
| 4.40 | 380 | 5.50 | 1,024 | 6.50 | 2,004 | 7.50 | 3,373 |
| 4.50 | 428 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904 and 1905. It is well defined. Above gage height, 5.6 feet, the table is the same as for 1904.

*Estimated monthly discharge of Naches River near North Yakima, Wash., for 1905.*

[Drainage area, 1,000 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 820 | 478 | 577 | 35,480 | 0.577 | 0.665 |
| February | 1,098 | 380 | 537 | 29,820 | .537 | .559 |
| March | 2,515 | 1,174 | 1,977 | 121,600 | 1.98 | 2.28 |
| April | 2,648 | 698 | 1,371 | 81,580 | 1.37 | 1.53 |
| May | 2,255 | 1,174 | 1,518 | 93,340 | 1.52 | 1.75 |
| June | 3,373 | 1,645 | 2,276 | 135,400 | 2.28 | 2.54 |
| July | 1,762 | 478 | 882 | 54,232 | .882 | 1.02 |
| August | 530 | 100 | 268 | 16,480 | .268 | .309 |
| September | 380 | 100 | 184 | 10,950 | .184 | .205 |
| October | 1,535 | 237 | 730 | 44,890 | .730 | .842 |
| November | 584 | 334 | 432 | 25,710 | .432 | .482 |
| December | 478 | 254 | 350 | 21,520 | .350 | .404 |
| The year | 2,648 | 100 | 925 | 671,000 | .926 | 12.39 |

NOTE.—Discharge interpolated for missing gage heights.

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## TIETON RIVER NEAR NORTH YAKIMA, WASH.

The gaging station on this stream was established April 14, 1902, at a point immediately below the mouth of Oak Creek, in sec. 3, T. 14 N., R. 16 E. of the Willamette meridian, about 22 miles from North Yakima by road.

The channel is straight for several hundred yards above and below the station. The banks do not overflow. The bed of the stream is rocky, with shifting gravel bars, which make it difficult to find suitable cross sections for meter measurements. There is but one channel at all stages. The underground flow at this station is estimated to be as much as 50 per cent of the measured flow.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is a cross chiseled in a ledge, with a black ring painted around it, near the west cable supports.

The gage is an inclined staff on the left bank of the stream. During 1905 it was read twice each day by Oscar Cobb. Bench marks were established as follows: (1) A point of rock on a ledge 12 feet from the gage; elevation, 15.67 feet. (2) A nail in a cottonwood stump 40 feet south of the gage; elevation, 15.93 feet. (3) The top of a bowlder 20 feet northwest of the cable-shear legs; elevation, 17.52 feet. Elevations refer to the datum of the gage, which is 1,683.36 feet above sea level.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 85, p 194; 100, p 382; 135, p 103.
Discharge: 85, p 195; 100, p 383; 135, p 103.
Discharge, monthly: 85, p 196; 100, p 384; 135, p 105.
Gage heights: 85, p 195; 135, p 104.
Rating table: 85, p 196; 100, p 384; 135, p 104.

*Discharge measurements of Tieton River near North Yakima, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 21 | W. J. Lightfoot | 111 | 178 | 3.4 | 7.90 | 605 |
| June 20 | do | 113 | 230 | 4.72 | 8.35 | 1,085 |
| September 6 | W. C. Muldrow | 109 | 126 | 2.74 | 7.20 | 325 |
| October 31 | do | 98 | 115 | 2.09 | 6.75 | 241 |
| November 20 | W. C. Sawyer | 98 | 110 | 2.16 | 6.80 | 249 |

*Daily gage height, in feet, of Tieton River near North Yakima, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.42 | 6.85 | 8.05 | 7.62 | 8.02 | 8.95 | 8.25 | 7.62 | 6.85 | 6.78 | 6.85 | 6.58 |
| 2 | 7.35 | 6.8 | 8.6 | 7.62 | 7.92 | 9.1 | 8.2 | 7.6 | 6.98 | 7.2 | 6.85 | 6.65 |
| 3 | 7.42 | 6.82 | 8.8 | 7.6 | 7.95 | 9.8 | 8.12 | 7.6 | 7.08 | 7.9 | 6.85 | 6.62 |
| 4 | 7.38 | 6.8 | 8.8 | 7.6 | 7.88 | 9.25 | 8.07 | 7.5 | 7.12 | 7.92 | 6.85 | 6.62 |
| 5 | 7.28 | 6.88 | 8.78 | 7.62 | 7.8 | 8.92 | 8.07 | 7.42 | 7.12 | 8.4 | 6.8 | 6.62 |
| 6 | 7.15 | 6.88 | 8.72 | 7.7 | 7.9 | 8.75 | 8.0 | 7.4 | 7.1 | 8.32 | 6.78 | 6.6 |
| 7 | 7.2 | 6.85 | 8.62 | 7.72 | 8.02 | 8.68 | 7.95 | 7.55 | 7.1 | 8.0 | 6.75 | 6.64 |
| 8 | 7.1 | 6.8 | 8.6 | 7.75 | 8.35 | 8.75 | 7.95 | 7.58 | 7.12 | 7.67 | 6.7 | 6.6 |
| 9 | 6.95 | 6.8 | 8.65 | 7.72 | 8.35 | 9.05 | 8.12 | 7.62 | 7.1 | 7.45 | 6.7 | 6.58 |
| 10 | 6.85 | 6.78 | 8.7 | 7.68 | 8.2 | 9.0 | 8.18 | 7.58 | 7.1 | 7.27 | 6.7 | 6.58 |
| 11 | 6.72 | 6.48 | 8.68 | 7.65 | 8.08 | 8.98 | 7.98 | 7.55 | 7.1 | 7.2 | 6.7 | 6.55 |
| 12 | 6.7 | 6.48 | 8.52 | 7.7 | 8.02 | 8.95 | 7.85 | 7.55 | 7.15 | 7.2 | 6.58 | 6.6 |
| 13 | 6.92 | 6.7 | 8.38 | 7.8 | 8.02 | 8.7 | 7.75 | 7.48 | 7.3 | 7.07 | 6.58 | 6.6 |
| 14 | 7.02 | 6.8 | 8.32 | 7.72 | 8.12 | 8.58 | 7.65 | 7.35 | 7.12 | 7.0 | 6.55 | 6.6 |
| 15 | 7.12 | 6.78 | 8.28 | 7.7 | 8.12 | 8.53 | 7.65 | 7.22 | 7.1 | 7.03 | 6.4 | 6.58 |
| 16 | 7.08 | 6.75 | 8.3 | 7.7 | 8.2 | 8.45 | 7.6 | 7.2 | 6.95 | 6.92 | 6.7 | 6.6 |



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*Daily gage height, in feet, of Tieton River near North Yakima, Wash., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 7.05 | 6.78 | 8.45 | 7.68 | 8.3 | 8.35 | 7.55 | 7.55 | 6.98 | 6.9 | 6.62 | 6.65 |
| 18 | 7.0 | 6.85 | 8.48 | 7.7 | 8.18 | 8.35 | 7.58 | 7.4 | 6.8 | 6.85 | 6.9 | 6.65 |
| 19 | 6.95 | 6.88 | 8.42 | 7.78 | 8.08 | 8.35 | 7.65 | 7.45 | 6.9 | 6.87 | 6.8 | 6.65 |
| 20 | 6.9 | 6.9 | 8.38 | 7.88 | 8.08 | 8.35 | 7.75 | 7.45 | 7.25 | 6.8 | 6.85 | 6.6 |
| 21 | 6.9 | 6.88 | 8.28 | 7.9 | 7.98 | 8.35 | 7.85 | 7.32 | 7.25 | 6.8 | 6.7 | 6.58 |
| 22 | 6.9 | 6.92 | 8.18 | 8.0 | 7.92 | 8.35 | 7.95 | 7.28 | 7.32 | 6.8 | 6.7 | 6.38 |
| 23 | 6.88 | 7.1 | 8.1 | 8.18 | 7.88 | 8.22 | 8.05 | 7.2 | 7.3 | 6.8 | 6.7 | 6.35 |
| 24 | 6.9 | 7.15 | 8.08 | 8.48 | 7.78 | 8.23 | 7.85 | 7.12 | 7.25 | 6.85 | 6.75 | 6.6 |
| 25 | 6.92 | 7.55 | 8.02 | 8.78 | 7.78 | 8.2 | 7.7 | 7.15 | 7.05 | 7.95 | 6.65 | 6.68 |
| 26 | 6.9 | 7.65 | 7.98 | 8.88 | 7.8 | 8.15 | 7.65 | 7.1 | 7.32 | 7.38 | 6.65 | 6.7 |
| 27 | 6.92 | 7.68 | 7.92 | 8.62 | 8.12 | 8.3 | 7.73 | 7.1 | 7.1 | 7.18 | 6.65 | 6.65 |
| 28 | 7.02 | 7.78 | 7.85 | 8.4 | 8.25 | 8.17 | 7.7 | 7.2 | 6.92 | 7.0 | 6.65 | 6.58 |
| 29 | 6.92 | ..... | 7.78 | 8.25 | 8.4 | 8.05 | 7.62 | 7.02 | 6.82 | 6.98 | 6.6 | 6.55 |
| 30 | 6.85 | ..... | 7.68 | 8.15 | 8.5 | 8.12 | 7.62 | 7.05 | 6.82 | 6.88 | 6.65 | 6.58 |
| 31 | 6.88 | ..... | 7.65 | ..... | 8.78 | ..... | 7.6 | 6.88 | ..... | 6.85 | ..... | 6.55 |

*Station rating table for Tieton River near North Yakima, Wash., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 6.30 | 195 | 7.20 | 335 | 8.10 | 755 | 9.00 | 1,790 |
| 6.40 | 202 | 7.30 | 365 | 8.20 | 830 | 9.10 | 1,940 |
| 6.50 | 210 | 7.40 | 400 | 8.30 | 920 | 9.20 | 2,090 |
| 6.60 | 220 | 7.50 | 440 | 8.40 | 1,020 | 9.30 | 2,240 |
| 6.70 | 233 | 7.60 | 480 | 8.50 | 1,130 | 9.40 | 2,390 |
| 6.80 | 249 | 7.70 | 525 | 8.60 | 1,250 | 9.50 | 2,540 |
| 6.90 | 267 | 7.80 | 575 | 8.70 | 1,380 | 9.60 | 2,700 |
| 7.00 | 287 | 7.90 | 630 | 8.80 | 1,510 | 9.70 | 2,860 |
| 7.10 | 310 | 8.00 | 690 | 8.90 | 1,650 | 9.80 | 3,020 |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904 and 1905. It is well defined between gage heights 6.7 feet and 7.3 feet. Above gage height, 8 feet, the table is uncertain.

*Estimated monthly discharge of Tieton River near North Yakima, Wash., for 1905.*

[Drainage area, 289 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 408 | 233 | 296 | 18,200 | 1.02 | 1.18 |
| February | 565 | 208 | 292 | 16,220 | 1.01 | 1.05 |
| March | 1,510 | 502 | 1,001 | 61,550 | 3.46 | 3.99 |
| April | 1,622 | 480 | 694 | 41,300 | 2.40 | 2.68 |
| May | 1,484 | 565 | 773 | 47,530 | 2.67 | 3.08 |
| June | 3,020 | 722 | 1,304 | 77,590 | 4.51 | 5.03 |
| July | 875 | 460 | 612 | 37,630 | 2.12 | 2.44 |
| August | 489 | 263 | 394 | 24,230 | 1.36 | 1.57 |
| September | 372 | 249 | 309 | 18,390 | 1.07 | 1.19 |
| October | 1,020 | 246 | 391 | 24,040 | 1.35 | 1.56 |
| November | 267 | 202 | 236 | 14,040 | .817 | .912 |
| December | 233 | 198 | 220 | 13,530 | .761 | .877 |
| The year | 3,020 | 198 | 544 | 394,200 | 1.88 | 25.56 |

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## SNAKE RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Snake River is the largest tributary of the Columbia. It rises on the northern slope of the Continental Divide in the Yellowstone National Park, draining the country west and southwest of Yellowstone Lake. From Shoshone, Lewis, and Hart lakes, near its head, the river flows in a southerly direction through a timbered and mountainous country for about 20 miles, when it broadens into Jackson Lake, a deep body of water about 3 miles wide and 8 miles long. Below the lake the river flows through Jackson Hole Valley—about 40 miles long and 8 miles wide—and then enters a long canyon near the Idaho-Wyoming line. All the large tributaries come from the east, receiving their waters from the Wind River Range. The west side of the valley is bounded by the high Teton Mountains, from which most of the drainage flows westward through Teton River into North Fork of Snake River. The Snake empties into Columbia River near Pasco Junction, Wash.

Bruneau River rises in northern Nevada and flows in a general northerly course through southern Idaho, emptying into Snake River at a point south of Boise. Fall River is one of the small tributaries of Snake River at its headwaters in eastern Idaho.

Boise River drains a mountainous and well-wooded country in Elmore County, Idaho, emptying into Snake River near the point where the Snake begins to form the boundary between Idaho and Oregon. The effects of the forests are shown in the high flow that is maintained throughout the summer season, in contrast to the discharge of Weiser River, father to the west, which drains a more barren country. In the lower course of the Boise a large number of canals divert water to irrigate lands in Boise Valley. The diverson of the water is now so great that frequent complaints of scarcity are heard.

Weiser River drains Washington County, in the extreme western part of Idaho, and flows into Snake River at Weiser, Idaho.

Owyhee River rises in northwestern Nevada and flows northwestward through Idaho; Malheur River rises in the mountains of east-central Oregon and empties into Snake River west of Boise; and the Grande Ronde drains the northern slope of the Blue Mountains and empties into Snake River in southeastern Washington.

The headwater tributaries of Palouse River have their sources in western Idaho. After passing into Washington the streams unite to form Palouse River, which has a general southwesterly course, through a rolling country. Six miles below Hooper, Wash., the Palouse bends suddenly to the south and enters a canyon, through which it flows to its junction with Snake River. A short distance above the mouth of the river are the Palouse Falls, approximately 180 feet high.

### NORTH FORK OF SNAKE RIVER NEAR ORA, IDAHO.

This station was established August 20, 1902, by N. S. Dils. It is located at the North Fork Bridge, 2 miles south of Ora and 10 miles above St. Anthony, Idaho.

The channel is straight both above and below this station. The banks are high and do not overflow. The bed of the stream is hard gravel, fairly smooth, and not liable to change. The current is swift.

Discharge measurements are made from the downstream side of the bridge, which consists of four spans resting on three rock-filled crib piers. The bridge is 210 feet long. The initial point for soundings is a bolt through the toe of the end brace on the lower side of the north end of the bridge.

The gage is a vertical staff fastened to the first bridge pier from the north abutment. During 1905 the gage was read once each day by Mrs. Martha J. Fritz. Bench marks were established as follows: (1) A United States Geological Survey aluminum tablet set in a large rock about 30 feet northeast from north end of bridge; elevation, 12.84 feet. (2) A cross on a large flat rock marked "B. M.," 25 feet northeast from north end of bridge; elevation, 11.10 feet. Elevations refer to the datum of the gage.

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Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; WS=Water-Supply Paper):

Description: WS 85, p 215; 100 p 455; 135,, p 170.
Discharge: WS 85, p 215; 100, p 455; 135, p 170.
Discharge, monthly: Ann 11, ii, p 105; WS 100, p 457; 135, p 172.
Gage heigths: WS 85, p 215; 100, p 456; 135, p 171.
Rating table: WS 100, p 456; 135, p 171.

*Discharge measurements of North Fork of Snake River near Ora, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 11 | E. C. La Rue | 178 | 393 | 3.37 | 2.30 | 1,325 |
| May 10 | do | 178 | 447 | 3.68 | 2.55 | 1,647 |
| June 28 | do | 176 | 380 | 3.12 | 2.25 | 1,186 |
| August 29 | do | 175 | 347 | 3.02 | 2.05 | 1,049 |
| September 18 | do | 174 | 360 | 2.83 | 2.05 | 1,019 |

*Daily gage height, in feet, of North Fork of Snake River near Ora, Idaho, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.2 | 2.1 | 2.1 | 2.0 | 2.7 | 2.5 | 2.2 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 2 | 2.2 | 2.1 | 2.1 | 2.1 | 2.6 | 2.5 | 2.2 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 3 | 2.1 | 2.1 | 2.1 | 2.1 | 2.6 | 2.5 | 2.2 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 4 | 2.1 | 2.1 | 2.0 | 2.1 | 2.6 | 2.5 | 2.2 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 5 | 2.2 | 2.1 | 2.0 | 2.1 | 2.5 | 2.4 | 2.2 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 6 | 2.2 | 2.1 | 2.0 | 2.1 | 2.5 | 2.4 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 7 | 2.1 | 2.1 | 2.0 | 2.2 | 2.5 | 2.4 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 8 | 2.1 | 2.1 | 2.0 | 2.2 | 2.5 | 2.4 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 9 | 2.1 | 2.1 | 2.0 | 2.3 | 2.6 | 2.4 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 10 | 2.1 | 2.1 | 2.0 | 2.3 | 2.6 | 2.4 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 11 | 2.1 | 2.1 | 2.0 | 2.3 | 2.5 | 2.4 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 12 | 2.1 | 2.1 | 2.0 | 2.3 | 2.5 | 2.4 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 13 | 2.1 | 2.1 | 2.0 | 2.3 | 2.6 | 2.4 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 14 | 2.1 | 2.1 | 2.0 | 2.3 | 2.6 | 2.4 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 15 | 2.2 | 2.1 | 2.1 | 2.3 | 2.6 | 2.3 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 16 | 2.2 | 2.1 | 2.1 | 2.5 | 2.6 | 2.3 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 17 | 2.2 | 2.1 | 2.1 | 2.5 | 2.6 | 2.3 | 2.1 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 18 | 2.2 | 2.1 | 2.1 | 2.4 | 2.6 | 2.3 | 2.1 | 2.0 | 2.0 | 2.1 | 2.0 | 2.0 |
| 19 | 2.2 | 2.2 | 2.1 | 2.5 | 2.6 | 2.3 | 2.1 | 2.0 | 2.0 | 2.1 | 2.0 | 2.0 |
| 20 | 2.2 | 2.2 | 2.1 | 2.5 | 2.6 | 2.3 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 21 | 2.2 | 2.2 | 2.1 | 2.6 | 2.6 | 2.3 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 22 | 2.2 | 2.2 | 2.1 | 2.6 | 2.6 | 2.3 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 23 | 2.1 | 2.2 | 2.1 | 2.7 | 2.6 | 2.3 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 24 | 2.1 | 2.2 | 2.1 | 2.9 | 2.5 | 2.3 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 25 | 2.1 | 2.2 | 2.1 | 2.9 | 2.5 | 2.3 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 26 | 2.1 | 2.1 | 2.1 | 2.9 | 2.5 | 2.2 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 27 | 2.1 | 2.1 | 2.1 | 2.9 | 2.5 | 2.2 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 28 | 2.1 | 2.1 | 2.1 | 2.7 | 2.5 | 2.2 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 29 | 2.1 | ..... | 2.1 | 2.7 | 2.5 | 2.2 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 | 2.0 |
| 30 | 2.1 | ..... | 2.1 | 2.7 | 2.5 | 2.2 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 | 2.0 |
| 31 | 2.1 | ..... | 2.0 | ..... | 2.5 | ..... | 2.1 | 2.0 | ..... | 2.0 | ..... | 2.0 |

NOTE.—No ice record.

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*Station rating table for North Fork of Snake River near Ora, Idaho, from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.00 | 990 | 2.30 | 1,280 | 2.60 | 1,730 | 2.90 | 2,280 |
| 2.10 | 1,070 | 2.40 | 1,420 | 2.70 | 1,900 | 3.00 | 2,480 |
| 2.20 | 1,160 | 2.50 | 1,570 | 2.80 | 2,090 | | |

The above table is applicable only for open-channel conditions. It is based on five discharge measurements made during 1905. It is well defined between gage heights 2 feet and 2.6 feet.

*Estimated monthly discharge of North Fork of Snake River near Ora, Idaho, for 1905.*

[Drainage area, 1,040 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 1,160 | 1,070 | 1,105 | 67,940 | 1.06 | 1.22 |
| February | 1,160 | 1,070 | 1,092 | 60,650 | 1.05 | 1.09 |
| March | 1,070 | 990 | 1,039 | 63,880 | .999 | 1.15 |
| April | 2,280 | 990 | 1,517 | 90,270 | 1.46 | 1.63 |
| May | 1,900 | 1,570 | 1,663 | 102,300 | 1.60 | 1.84 |
| June | 1,570 | 1,160 | 1,345 | 80,040 | 1.29 | 1.44 |
| July | 1,160 | 1,070 | 1,085 | 66,720 | 1.04 | 1.20 |
| August | 1,070 | 990 | 1,034 | 63,580 | .994 | 1.15 |
| September | 1,070 | 990 | 995 | 59,210 | .957 | 1.07 |
| October | 1,070 | 990 | 1,039 | 63,880 | .999 | 1.15 |
| November | 990 | 990 | 990 | 58,910 | .952 | 1.06 |
| December | 990 | 990 | 990 | 60,870 | .952 | 1.10 |
| The year | 2,280 | 990 | 1,158 | 838,200 | 1.11 | 15.10 |

## SNAKE RIVER NEAR MINIDOKA, IDAHO.

This station was originally established August 5, 1895, at Montgomery's ferry, on the stage road from Minidoka to Albion, 4 miles east of Rupert, Idaho, and 10 miles below the diversion dam for the Minidoka irrigation project. Measurements at Montgomery's ferry show the amount of water available for irrigation purposes there and for the newly constructed Twin Falls canals heading 23 miles below, and also the conditions that will exist for power purposes at Shoshone Falls, about 45 miles below, after the irrigable lands of Snake River Valley shall have been reclaimed.

The channel is straight for 2,000 feet above and 1,500 feet below the station. The velocity is low at all stages. Both banks are inclined up to gage height 6 to 9 feet, and then become vertical. Both are clean, sandy, and do not overflow. The bed of the stream is composed of sand and coarse gravel and is practically permanent. There is but one channel at all stages.

Discharge measurements are made from the ferryboat. A tagged wire has been stretched above the ferry cable. The initial point for soundings is the face of the cable support on the right bank.

Since the station was established the gage has several times been disturbed by the shifting quicksand and reestablished. The present gage is a staff constructed in three independent sections on the right bank. The lower inclined section, reading from 0 to 3.3 feet, may move in the quicksand without disturbing the upper sections. Above gage height 6.6 feet

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the gage is vertical. During 1905 the gage was read twice each day by George Montgomery. The bench mark is a United States Geological Survey iron post on the right bank, 200 feet below the gage; elevation, 12.67 feet above the datum of the gage.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; Bull=Bulletin: WS=Water-Supply Paper):

Description: Ann 18, iv, pp 334–335; Bull 140, p 241; WS 16, p 165; 58, p 155; 38, pp 351–352; 51, p 426; 66, p 126; 85, pp 213–214; 100, p 443; 135, pp 172–173.

Discharge: Ann 18, iv, p 335; Bull 140, p 241; WS 16, p 165; 28, p 168; 38, p 352; 51, p 426; 66, p 126; 85 p 214; 100, p 444; 135, p 173.

Discharge, monthly: Ann 18, iv, p 336; 19, iv, p 447; 20, iv, pp 473, 474; 21, iv, p 405; WS 100, p 445; 135, p 175.

Discharge, yearly: Ann 20, iv, p 61.

Gage heights: Bull 140, p 231; WS 11, p 80; 16, p 165; 28, p 160; 38, p 352; 66, p 127; 85, p 214; 100, p 444; 135, pp 173–174.

Hydrographs: Ann 19, iv, p 448; 20, iv, p 475; 21, iv, p 406.

Rainfall and run-off relation: Ann 20, iv, p 744.

Rating tables: Ann 18, iv, p 335; 19, iv, p 447; WS 28, p 169; 39, p 453; 100, p 445; 135, p 174.

*Discharge measurements of Snake River near Minidoka, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 21 | E. C. La Rue | 828 | 3,938 | 1.51 | 3.10 | 5,949 |
| May 20 | do | 845 | 4,818 | 1.69 | 3.90 | 8,138 |
| June 6 | do | 850 | 5,718 | 2.14 | 5.15 | 12,230 |
| June 16 | Hoyt and La Rue | 845 | 5,588 | 2.07 | 5.05 | 11,560 |
| July 16 | E. C. La Rue | 795 | 3,212 | 1.27 | 2.40 | 4,092 |
| August 12 | do | 770 | 2,258 | .87 | 1.20 | 1,963 |
| October 23 | do | 795 | 3,269 | 1.23 | 2.31 | 4,009 |

*Daily gage height, in feet, of Snake River near Minidoka, Idaho, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.45 | 3.05 | 3.05 | 2.95 | 3.9 | 4.65 | 3.75 | 1.4 | 1.2 | 1.35 | 2.4 | 2.6 |
| 2 | 4.1 | 3.05 | 3.05 | 2.9 | 3.9 | 4.65 | 3.95 | 1.4 | 1.2 | 1.4 | 2.4 | 2.75 |
| 3 | 4.0 | 2.95 | 3.15 | 2.85 | 3.9 | 4.65 | 3.75 | 1.35 | 1.15 | 1.45 | 2.4 | 2.8 |
| 4 | 3.85 | 2.9 | 3.0 | 2.75 | 3.9 | 4.8 | 3.6 | 1.3 | 1.15 | 1.55 | 2.45 | 2.55 |
| 5 | 3.65 | 2.85 | 3.0 | 2.7 | 3.95 | 5.0 | 3.5 | 1.25 | 1.2 | 1.6 | 2.5 | 2.55 |
| 6 | 3.6 | 2.75 | 3.15 | 2.7 | 4.2 | 5.1 | 3.4 | 1.2 | 1.2 | 1.65 | 2.5 | 2.55 |
| 7 | 3.5 | 2.85 | 3.25 | 2.6 | 4.2 | 5.55 | 3.35 | 1.2 | 1.2 | 1.7 | 2.5 | 2.55 |
| 8 | 3.5 | 2.9 | 3.25 | 2.6 | 4.2 | 5.6 | 3.15 | 1.2 | 1.2 | 1.75 | 2.5 | 2.55 |
| 9 | 3.5 | 3.05 | 3.05 | 2.6 | 4.1 | 5.3 | 2.95 | 1.2 | 1.2 | 1.8 | 2.5 | 2.55 |
| 10 | 3.5 | 3.05 | 2.95 | 2.7 | 4.0 | 5.0 | 2.8 | 1.2 | 1.2 | 1.85 | 2.5 | 2.8 |
| 11 | 3.35 | 3.35 | 2.95 | 2.7 | 4.0 | 5.0 | 2.7 | 1.2 | 1.2 | 1.9 | 2.5 | 3.35 |
| 12 | 3.25 | 3.8 | 2.85 | 2.8 | 4.0 | 5.35 | 2.7 | 1.2 | 1.2 | 2.0 | 2.5 | 3.65 |
| 13 | 3.3 | 4.25 | 2.85 | 2.95 | 4.0 | 5.6 | 2.6 | 1.2 | 1.2 | 2.1 | 2.5 | 3.2 |
| 14 | 3.45 | 3.75 | 2.85 | 2.95 | 4.0 | 5.35 | 2.6 | 1.2 | 1.2 | 2.15 | 2.5 | 3.1 |
| 15 | 3.55 | 3.45 | 2.85 | 2.95 | 4.0 | 5.15 | 2.5 | 1.2 | 1.2 | 2.2 | 2.5 | 3.1 |
| 16 | 3.65 | 3.2 | 2.85 | 2.95 | 4.0 | 5.05 | 2.4 | 1.2 | 1.2 | 2.25 | 2.5 | 3.1 |
| 17 | 3.8 | 3.1 | 2.85 | 2.95 | 3.9 | 5.1 | 2.3 | 1.2 | 1.15 | 2.25 | 2.5 | 3.1 |
| 18 | 3.85 | 2.9 | 2.85 | 2.95 | 3.85 | 5.25 | 2.3 | 1.2 | 1.15 | 2.25 | 2.5 | 3.1 |
| 19 | 3.95 | 3.05 | 2.85 | 2.95 | 3.8 | 5.25 | 2.15 | 1.2 | 1.15 | 2.25 | 2.5 | 3.1 |
| 20 | 4.0 | 3.35 | 2.85 | 3.05 | 3.8 | 5.15 | 2.1 | 1.2 | 1.15 | 2.25 | 2.5 | 3.2 |
| 21 | 4.15 | 3.6 | 2.85 | 3.05 | 4.25 | 4.9 | 2.0 | 1.1 | 1.15 | 2.5 | 2.6 | 3.35 |
| 22 | 4.2 | 3.8 | 2.95 | 3.05 | 4.45 | 4.6 | 2.0 | 1.15 | 1.15 | 2.4 | 2.6 | 3.4 |
| 23 | 3.9 | 2.75 | 3.0 | 3.1 | 4.6 | 4.35 | 1.9 | 1.2 | 1.15 | 2.35 | 2.6 | 3.4 |
| 24 | 3.6 | 2.85 | 2.85 | 3.25 | 4.75 | 4.1 | 1.8 | 1.2 | 1.2 | 2.3 | 2.6 | 3.4 |

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*Daily gage height, in feet, of Snake River near Minidoka, Idaho, for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 3.2 | 2.85 | 2.95 | 3.25 | 4.7 | 3.95 | 1.75 | 1.2 | 1.2 | 2.3 | 2.6 | 3.4 |
| 26 | 3.05 | 2.9 | 2.95 | 3.4 | 4.5 | 3.9 | 1.7 | 1.2 | 1.2 | 2.25 | 2.6 | 3.3 |
| 27 | 3.05 | 3.05 | 3.0 | 3.6 | 4.25 | 3.85 | 1.6 | 1.2 | 1.25 | 2.25 | 2.6 | 3.0 |
| 28 | 3.05 | 3.05 | 3.05 | 3.7 | 4.15 | 3.7 | 1.5 | 1.15 | 1.25 | 2.3 | 2.6 | 2.95 |
| 29 | 3.05 | ..... | 3.05 | 3.8 | 4.3 | 3.6 | 1.5 | 1.15 | 1.25 | 2.3 | 2.6 | 3.1 |
| 30 | 3.05 | ..... | 3.05 | 3.9 | 4.35 | 3.7 | 1.45 | 1.15 | 1.25 | 2.35 | 2.6 | 3.0 |
| 31 | 3.05 | ..... | 3.05 | ..... | 4.55 | ..... | 1.4 | 1.15 | ..... | 2.4 | ..... | 3.1 |

NOTE.—The river was frozen over January 1-25; February 11-17, 20-22, and December 2, 3, 10-31.

*Station rating table for Snake River near Minidoka, Idaho, from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.10 | 1,890 | 2.30 | 3,940 | 3.50 | 7,060 | 4.70 | 10,580 |
| 1.20 | 1,960 | 2.40 | 4,180 | 3.60 | 7,340 | 4.80 | 10,890 |
| 1.30 | 2,060 | 2.50 | 4,430 | 3.70 | 7,630 | 4.90 | 11,210 |
| 1.40 | 2,190 | 2.60 | 4,680 | 3.80 | 7,920 | 5.00 | 11,540 |
| 1.50 | 2,340 | 2.70 | 4,930 | 3.90 | 8,210 | 5.10 | 11,880 |
| 1.60 | 2,500 | 2.80 | 5,180 | 4.00 | 8,500 | 5.20 | 12,230 |
| 1.70 | 2,670 | 2.90 | 5,440 | 4.10 | 8,790 | 5.30 | 12,590 |
| 1.80 | 2,860 | 3.00 | 5,700 | 4.20 | 9,080 | 5.40 | 12,950 |
| 1.90 | 3,060 | 3.10 | 5,970 | 4.30 | 9,380 | 5.50 | 13,320 |
| 2.00 | 3,270 | 3.20 | 6,240 | 4.40 | 9,680 | 5.60 | 13,700 |
| 2.10 | 3,480 | 3.30 | 6,510 | 4.50 | 9,980 | 5.70 | 14,090 |
| 2.20 | 3,700 | 3.40 | 6,780 | 4.60 | 10,280 | | |

The above table is applicable only for open-channel conditions. It is based on seven discharge measurements made during 1905. It is well defined between gage heights 1 foot and 5.2 feet.

*Estimated monthly discharge of Snake River near Minidoka, Idaho, for 1905.*

[Drainage area, 17,900 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | ..... | ..... | 5,800 | 356,600 | 0.324 | 0.374 |
| February | ..... | ..... | 5,550 | 308,200 | .310 | .323 |
| March | 6,375 | 5,310 | 5,641 | 346,900 | .315 | .363 |
| April | 8,210 | 4,680 | 5,780 | 343,900 | .323 | .360 |
| May | 10,740 | 7,920 | 8,925 | 548,800 | .499 | .575 |
| June | 13,700 | 7,340 | 10,910 | 649,100 | .609 | .680 |
| July | 8,355 | 2,190 | 4,545 | 279,500 | .254 | .293 |
| August | 2,190 | 1,880 | 1,976 | 121,500 | .110 | .127 |
| September | 2,010 | 1,920 | 1,955 | 116,300 | .109 | .122 |
| October | 4,430 | 2,125 | 3,415 | 210,000 | .191 | .220 |
| November | 4,680 | 4,180 | 4,484 | 266,800 | .251 | .280 |
| December | ..... | ..... | 4,550 | 279,800 | .254 | .293 |
| The year | ..... | ..... | 5,294 | 3,827,000 | .296 | 4.01 |

[a] Exclusive of drainage areas of lost rivers. Revised since previous reports.

NOTE.—Monthly means for January, February, and December estimated from flow during open periods.

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## LOW-WATER CONDITIONS ON SNAKE RIVER BETWEEN BLACKFOOT AND SHOSHONE FALLS, IDAHO.

The low-water conditions on Snake River, between Blackfoot and Shoshone Falls, were clearly brought out by a series of measurements made during August, 1905. This investigation was carried on by the Geological Survey in conjunction with the State engineer's office.

The entire supply of upper Snake River available above Blackfoot, Idaho, is used for irrigation during August and September. On August 10 there was 184 second-feet available at the American Falls Power Company canal heading. This canal, which diverts at a point 8 miles above Blackfoot, is to supply water for 80,000 acres of land. Beginning at a point 4 miles above the Blackfoot wagon bridge, Snake River channel was entirely dry for a distance of 10 miles. Following is a summary of the measurements:

*Low-water measurements of Snake River and Twin Falls canal in 1905.*

| Date. | Stream. | Location. | Discharge. |
|---|---|---|---|
| | | | *Second-feet.* |
| August 9 | Snake River | Just below mouth of Black River | 39 |
| August 10 | do | Just above American Falls canal heading | 184 |
| August 11 | do | Just above American Falls | 1,996 |
| August 12 | do | At Montgomery's Ferry | 1,983 |
| August 14 | do | Between Shoshone Falls and Twin Falls | [a]1,348 |
| August 15 | Twin Falls canal | | 1,008 |

[a] Includes the waste from the Twin Falls canal.

A further investigation was carried on by the United States Geological Survey to determine the loss or gain in Snake River between Montgomery's Ferry and Shoshone Falls. August 22 the discharge of Snake River between Twin Falls and Shoshone Falls was 1,299 second-feet and the discharge from springs between the point of measurement and Shoshone Falls was 17 second-feet, making the total discharge of Snake River at Shoshone Falls 1,316 second-feet.

The result of this investigation may be tabulated as follows:

*Loss in Snake River between Montgomery's Ferry and Shoshone Falls in 1905.*

| Date. | | Discharge. | |
|---|---|---|---|
| | | *Second-feet.* | *Second-feet.* |
| August 22 | Total discharge Snake River at Montgomery's Ferry | | 1,910 |
| Do. | Total discharge Snake River at Shoshone Falls | 1,316 | |
| Do. | Amount diverted by Twin Falls canal | 1,008 | |
| August 23 | Measured waste from Twin Falls canal reaching the river above Shoshone Falls. | | 187 |
| Do. | Loss by seepage from the Twin Falls canal during the first 20 miles of its course (which is assumed to return to the river. | | 371 |
| Do. | Loss in Snake River between Montgomery's Ferry and Shoshone Falls. | 144 | |
| | | 2,468 | 2,468 |

The loss of 371 second-feet in the Twin Falls canal was determined by a special series of measurements made on August 22 and 23, 1905. The canal follows the river at a distance of one-half to 1 mile from its bank, and it is therefore reasonably correct to assume that this seepage all reaches the river.

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In September, 1902, a similar investigation was made and the loss between Montgomery's Ferry and Shoshone Falls was found to be 196 second-feet.

## FALL RIVER AT FREMONT, IDAHO.

This station supersedes the station at Wilson's mill, near Marysville, which was discontinued December 31, 1903, because of the difficulty of securing an observer. It was established January 1, 1904.

The channel is straight above and below the station. Both banks are high, wooded, steep, and not liable to overflow. There is but one channel at all stages. The Brady canal, capacity about 100 second-feet, heads in the right bank of the river between Wilson's mill and the Fremont station.

Discharge measurements are made by means of a cable and car. The initial point for soundings is a tin tag marked "I. P." on the inside face of the cable on the south bank of the stream.

The gage is a vertical staff on the south bank, about 900 feet from Fremont post-office. During 1905 the gage was read twice each day by Mrs. Eva A. Loomis. The bench mark is a standard aluminum tablet set in a rock 20 feet from the gage; elevation, 10.36 feet above the datum of the gage.

*Discharge measurements of Fall River at Fremont, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 12 | E. C. La Rue | 139 | 185 | 2.55 | 1.95 | 472 |
| May 11 | do | 145 | 284 | 3.75 | 2.65 | 1,065 |
| June 28 | do | 146 | 467 | 5.67 | 4.00 | 2,650 |
| August 29 | do | 140 | 178 | 2.16 | 1.85 | 384 |

*Daily gage height, in feet, of Fall River at Fremont, Idaho, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.0 | 1.8 | 2.0 | 1.6 | 2.8 | 3.45 | 3.7 | 1.9 | 1.9 | 2.0 | 1.9 | 1.85 |
| 2 | 2.0 | 1.8 | 2.0 | 1.6 | 2.8 | 3.6 | 3.1 | 1.9 | 1.9 | 1.95 | 1.9 | 1.85 |
| 3 | 2.0 | 1.8 | 2.0 | 1.6 | 2.8 | 3.7 | 3.0 | 1.85 | 1.9 | 1.95 | 1.9 | 1.85 |
| 4 | 2.0 | 1.8 | 2.0 | 1.6 | 2.6 | 3.85 | 3.1 | 1.9 | 1.9 | 1.95 | 1.9 | 1.8 |
| 5 | 2.0 | 1.8 | 2.0 | 1.4 | 2.65 | 4.0 | 3.0 | 1.9 | 1.9 | 1.95 | 1.85 | 1.8 |
| 6 | 2.0 | 1.8 | 2.0 | 1.6 | 2.75 | 3.8 | 3.05 | 1.9 | 1.85 | 1.95 | 1.85 | 1.8 |
| 7 | 2.0 | 1.8 | 2.0 | 1.8 | 2.75 | 3.75 | 3.15 | 1.85 | 1.85 | 1.85 | 1.85 | 1.8 |
| 8 | 2.0 | 1.8 | 2.0 | 1.8 | 2.9 | 3.9 | 2.9 | 1.85 | 1.9 | 1.85 | 1.85 | 1.8 |
| 9 | 2.0 | 1.8 | 2.0 | 1.8 | 2.8 | 4.0 | 2.8 | 1.85 | 1.9 | 1.85 | 1.85 | 1.8 |
| 10 | 2.0 | 1.8 | 2.0 | 1.8 | 2.7 | 4.05 | 3.05 | 1.85 | 1.9 | 1.85 | 1.85 | ..... |
| 11 | 2.0 | 1.8 | 2.0 | 1.6 | 2.7 | 3.75 | 2.7 | 1.85 | 1.9 | 1.85 | 1.85 | ..... |
| 12 | 2.0 | ..... | 1.8 | 1.8 | 2.65 | 3.6 | 2.8 | 1.85 | 1.9 | 1.9 | 1.85 | ..... |
| 13 | 2.0 | ..... | 1.8 | 1.8 | 2.65 | 3.75 | 2.75 | 1.85 | 1.9 | 1.9 | 1.85 | ..... |
| 14 | 2.0 | ..... | 1.8 | 1.8 | 2.75 | 3.85 | 2.65 | 1.85 | 1.9 | 1.9 | 1.85 | ..... |
| 15 | 2.0 | ..... | 1.8 | 1.8 | 2.75 | 3.75 | 2.35 | 1.85 | 1.9 | 1.9 | 1.85 | ..... |
| 16 | 2.0 | ..... | 1.8 | 1.8 | 2.8 | 3.6 | 2.25 | 1.85 | 1.9 | 1.9 | 1.85 | ..... |
| 17 | 1.8 | ..... | 1.8 | 2.0 | 2.9 | 3.5 | 2.15 | 1.85 | 1.9 | 1.9 | 1.85 | ..... |
| 18 | 1.8 | ..... | 1.8 | 2.0 | 3.2 | 3.6 | 2.1 | 1.85 | 1.9 | 1.9 | 1.85 | ..... |
| 19 | 1.8 | ..... | 1.8 | 2.1 | 3.25 | 3.1 | 2.1 | 1.85 | 1.9 | 1.85 | 1.85 | ..... |
| 20 | 1.8 | ..... | 1.8 | 2.2 | 3.2 | 2.9 | 2.1 | 1.85 | 1.9 | 1.85 | 1.85 | ..... |

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*Daily gage height, in feet, of Fall River at Fremont, Idaho, for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 1.8 | ..... | 1.6 | 2.25 | 3.2 | 2.85 | 2.05 | 1.85 | 1.85 | 1.9 | 1.85 | ..... |
| 22 | 1.8 | ..... | 1.6 | 2.3 | 3.25 | 3.1 | 2.0 | 1.85 | 1.85 | 1.9 | 1.85 | ..... |
| 23 | 1.8 | ..... | 1.6 | 2.4 | 3.5 | 3.15 | 1.95 | 1.85 | 1.85 | 1.9 | 1.85 | ..... |
| 24 | 1.8 | ..... | 1.6 | 2.5 | 2.85 | 3.2 | 1.9 | 1.85 | 1.9 | 1.9 | 1.85 | ..... |
| 25 | 1.8 | ..... | 1.6 | 2.95 | 2.9 | 3.3 | 1.9 | 1.85 | 1.95 | 1.9 | 1.85 | ..... |
| 26 | 1.8 | ..... | 1.6 | 3.5 | 3.0 | 3.5 | 1.9 | 1.9 | 1.95 | 1.9 | 1.85 | ..... |
| 27 | 1.8 | ..... | 1.6 | 2.9 | 3.2 | 3.9 | 1.9 | 1.9 | 1.95 | 1.9 | 1.85 | ..... |
| 28 | 1.8 | ..... | 1.6 | 2.7 | 3.35 | 4.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.85 | ..... |
| 29 | 1.8 | ..... | 1.6 | 2.75 | 3.6 | 3.8 | 1.8 | 1.9 | 1.9 | 1.9 | 1.85 | ..... |
| 30 | 1.8 | ..... | 1.6 | 2.8 | 3.5 | 3.6 | 1.9 | 1.9 | 2.0 | 1.9 | 1.85 | ..... |
| 31 | 1.8 | ..... | 1.6 | ..... | 3.45 | ..... | 1.9 | 1.9 | ..... | 1.9 | ..... | ..... |

NOTE.—River frozen over February 12–28 and December 12–31.

*Station rating table for Fall River at Fremont, Idaho, from October 28, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.40 | 168 | 2.10 | 575 | 2.80 | 1,215 | 3.50 | 2,030 |
| 1.50 | 210 | 2.20 | 655 | 2.90 | 1,325 | 3.60 | 2,150 |
| 1.60 | 255 | 2.30 | 740 | 3.00 | 1,440 | 3.70 | 2,275 |
| 1.70 | 305 | 2.40 | 825 | 3.10 | 1,555 | 3.80 | 2,400 |
| 1.80 | 365 | 2.50 | 915 | 3.20 | 1,670 | 3.90 | 2,525 |
| 1.90 | 430 | 2.60 | 1,010 | 3.30 | 1,790 | 4.00 | 2,650 |
| 2.00 | 500 | 2.70 | 1,110 | 3.40 | 1,910 | | |

The above table is applicable only for open-channel conditions. It is based on four discharge measurements made during 1905. It is not well defined.

*Estimated monthly discharge of Fall River at Fremont, Idaho, for 1904.*

[Drainage area, 390 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| November | 575 | 500 | 532 | 31,660 | 1.36 | 1.52 |
| December | 538 | 500 | 510 | 31,360 | 1.31 | 1.51 |

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*Estimated monthly discharge of Fall River at Fremont, Idaho, for 1905.*

[Drainage area, 390 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 500 | 365 | 435 | 26,750 | 1.12 | 1.29 |
| February 1-11 | 365 | 365 | 365 | 7,964 | .936 | .383 |
| March | 500 | 255 | 374 | 23,000 | .959 | 1.11 |
| April | 2,030 | 168 | 620 | 36,890 | 1.59 | 1.77 |
| May | 2,150 | 1,010 | 1,419 | 87,250 | 3.64 | 4.20 |
| June | 2,712 | 1,270 | 2,154 | 128,200 | 5.52 | 6.16 |
| July | 2,275 | 365 | 924 | 56,820 | 2.37 | 2.73 |
| August | 430 | 398 | 409 | 25,150 | 1.05 | 1.21 |
| September | 500 | 398 | 430 | 25,590 | 1.10 | 1.23 |
| October | 500 | 398 | 431 | 26,500 | 1.11 | 1.28 |
| November | 430 | 398 | 402 | 23,920 | 1.03 | 1.15 |
| December 1-9 | 398 | 365 | 376 | 6,712 | .964 | .323 |
| The period | | | | 474,700 | | |

NOTE.—No estimate for ice period.

## TETON RIVER NEAR ST. ANTHONY, IDAHO.

This station was established April 23, 1903, by N. S. Dils. It is located at the bridge on the stage road from St. Anthony to Victor, Idaho.

The channel is straight for a short distance above and below the station. The right bank is high and will not overflow. The left bank will overflow at extreme flood stages. The current is sluggish. Both banks and bed are composed of hard gravel, and the latter is permanent.

Discharge measurements are made from the two-span bridge to which the gage is attached. The bridge is supported by crib abutments, constructed of logs and filled with lava rock, and by a similar middle pier. The initial point from which soundings are made is a large bolt marked "I. P." in the upstream side of the south abutment.

The gage is a vertical staff spiked to the upstream side of the north abutment of the bridge. During 1905 the gage was read once each day by William Ferguson. Bench marks were established as follows: (1) A United States Geological Survey aluminum tablet set in solid rock about 30 feet northeast of the north end of the bridge; elevation, 13.53 feet. (2) A cross on a large flat rock 40 feet northeast of the right end of the bridge, marked "B. M."; elevation, 14.25 feet. (3) A similar rock 60 feet northwest of the right end of the bridge, similarly marked; elevation, 14.41 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 453; 135, p 177.
Discharge: 100, p 453; 135, p 177.
Discharge, monthly: 100, p 455; 135, p 179.
Gage heights: 100, p 454; 135, p 178.
Rating table: 100, p 454; 135, p 178.

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*Discharge measurements of Teton River near St. Anthony, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 13 | E. C. La Rue | 81 | 306 | 1.22 | 1.50 | 371 |
| May 12 | do | 80 | 349 | 1.86 | 1.95 | 646 |
| June 14 | do | 80 | 457 | 3.29 | 3.10 | 1,504 |
| June 29 | do | 80 | 407 | 2.78 | 2.60 | 1,131 |
| August 28 | do | 79.5 | 322 | 1.49 | 1.70 | 478 |

*Daily gage height, in feet, of Teton River near St. Anthony, Idaho, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.1 | 1.4 | 1.3 | 1.4 | 1.85 | 3.15 | 2.55 | 1.7 | 1.65 | 1.5 | 1.5 | 1.6 |
| 2 | 2.0 | 1.4 | 1.3 | 1.45 | 1.95 | 3.25 | 2.45 | 1.7 | 1.65 | 1.5 | 1.5 | 1.65 |
| 3 | 2.0 | 1.4 | 1.3 | 1.5 | 1.9 | 3.4 | 2.4 | 1.7 | 1.65 | 1.5 | 1.5 | 1.65 |
| 4 | 1.95 | 1.4 | 1.3 | 1.5 | 1.95 | 3.4 | 2.35 | 1.7 | 1.65 | 1.5 | 1.5 | 1.65 |
| 5 | 1.95 | 1.4 | 1.35 | 1.5 | 2.0 | 3.4 | 2.3 | 1.7 | 1.65 | 1.5 | 1.5 | 1.65 |
| 6 | 1.95 | 1.4 | 1.35 | 1.55 | 2.0 | 3.1 | 2.3 | 1.7 | 1.65 | 1.5 | 1.5 | 1.55 |
| 7 | 1.95 | 1.4 | 1.4 | 1.6 | 2.05 | 3.1 | 2.3 | 1.7 | 1.6 | 1.5 | 1.5 | 1.55 |
| 8 | 1.95 | 1.4 | 1.4 | 1.6 | 2.1 | 3.1 | 2.25 | 1.7 | 1.6 | 1.5 | 1.5 | 1.6 |
| 9 | 1.95 | 1.4 | 1.4 | 1.55 | 2.15 | 3.2 | 2.25 | 1.7 | 1.6 | 1.5 | 1.5 | 1.6 |
| 10 | 1.95 | 1.4 | 1.4 | 1.5 | 2.15 | 3.25 | 2.25 | 1.65 | 1.6 | 1.5 | 1.5 | 1.6 |
| 11 | 2.0 | 1.6 | 1.4 | 1.55 | 2.1 | 2.9 | 2.25 | 1.65 | 1.6 | 1.5 | 1.5 | 1.7 |
| 12 | 2.1 | 1.95 | 1.4 | 1.5 | 2.0 | 2.9 | 2.2 | 1.6 | 1.55 | 1.5 | 1.5 | ..... |
| 13 | 2.1 | 1.95 | 1.5 | 1.5 | 1.85 | 3.0 | 2.2 | 1.6 | 1.55 | 1.5 | 1.5 | ..... |
| 14 | 2.1 | 1.95 | 1.6 | 1.5 | 1.9 | 3.0 | 2.15 | 1.6 | 1.55 | 1.5 | 1.5 | ..... |
| 15 | 2.1 | 2.0 | 1.7 | 1.5 | 1.95 | 3.0 | 2.1 | 1.6 | 1.5 | 1.5 | 1.5 | ..... |
| 16 | 2.1 | 2.0 | 1.9 | 1.5 | 2.1 | 3.0 | 2.05 | 1.55 | 1.5 | 1.5 | 1.5 | ..... |
| 17 | 2.15 | 2.3 | 2.0 | 1.5 | 2.4 | 2.8 | 2.0 | 1.55 | 1.5 | 1.5 | 1.5 | ..... |
| 18 | 2.15 | 2.5 | 2.2 | 1.5 | 2.55 | 2.7 | 1.95 | 1.55 | 1.5 | 1.5 | 1.5 | ..... |
| 19 | 2.15 | 2.5 | 2.1 | 1.5 | 2.7 | 2.7 | 1.9 | 1.55 | 1.5 | 1.5 | 1.5 | ..... |
| 20 | 2.15 | 2.6 | 1.95 | 1.55 | 2.75 | 2.6 | 1.9 | 1.55 | 1.5 | 1.55 | 1.5 | ..... |
| 21 | 2.15 | 2.6 | 1.8 | 1.6 | 2.8 | 2.4 | 1.85 | 1.55 | 1.5 | 1.55 | 1.5 | ..... |
| 22 | 2.1 | 2.5 | 1.75 | 1.6 | 2.8 | 2.4 | 1.85 | 1.6 | 1.45 | 1.55 | 1.5 | ..... |
| 23 | 2.0 | 2.5 | 1.65 | 1.6 | 2.4 | 2.4 | 1.8 | 1.6 | 1.45 | 1.55 | 1.5 | ..... |
| 24 | 1.8 | 2.45 | 1.6 | 1.75 | 2.3 | 2.4 | 1.75 | 1.6 | 1.45 | 1.55 | 1.5 | ..... |
| 25 | 1.7 | 2.4 | 1.5 | 1.9 | 2.25 | 2.4 | 1.75 | 1.65 | 1.45 | 1.55 | 1.5 | ..... |
| 26 | 1.4 | 1.3 | 1.8 | 1.8 | 2.45 | 2.4 | 1.75 | 1.65 | 1.45 | 1.5 | 1.5 | ..... |
| 27 | 1.4 | 1.3 | 1.9 | 1.7 | 2.7 | 2.4 | 1.75 | 1.65 | 1.45 | 1.5 | 1.5 | ..... |
| 28 | 1.4 | 1.3 | 1.8 | 1.7 | 2.9 | 2.45 | 1.7 | 1.65 | 1.45 | 1.5 | 1.5 | ..... |
| 29 | 1.4 | ..... | 1.75 | 1.7 | 3.05 | 2.6 | 1.7 | 1.65 | 1.55 | 1.5 | 1.55 | ..... |
| 30 | 1.4 | ..... | 1.6 | 1.8 | 2.8 | 2.6 | 1.7 | 1.65 | 1.55 | 1.5 | 1.55 | ..... |
| 31 | 1.4 | ..... | 1.5 | ..... | 2.95 | ..... | 1.7 | 1.65 | ..... | 1.5 | ..... | ..... |

NOTE.—River frozen over January 1 to February 28, and December 12 to 31.

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*Station rating table for Teton River near St. Anthony, Idaho, from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet* |
| 1.30 | 253 | 1.90 | 610 | 2.50 | 1,024 | 3.00 | 1,417 |
| 1.40 | 310 | 2.00 | 674 | 2.60 | 1,100 | 3.10 | 1,500 |
| 1.50 | 368 | 2.10 | 740 | 2.70 | 1,177 | 3.20 | 1,584 |
| 1.60 | 427 | 2.20 | 808 | 2.80 | 1,255 | 3.30 | 1,669 |
| 1.70 | 487 | 2.30 | 878 | 2.90 | 1,335 | 3.40 | 1,755 |
| 1.80 | 548 | 2.40 | 950 | | | | |

The above table is strictly applicable only for open-channel conditions. It is based on five discharge measurements made during 1905. It is well defined between gage heights 1.5 feet and 3.1 feet.

*Estimated monthly discharge of Teton River near St. Anthony, Idaho, for 1905.*

[Drainage area, 960 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| March | 808 | 253 | 438 | 26,930 | 0.456 | 0.526 |
| April | 610 | 310 | 416 | 24,750 | .433 | .483 |
| May | 1,458 | 579 | 902 | 55,460 | .940 | 1.08 |
| June | 1,755 | 950 | 1,301 | 77,420 | 1.36 | 1.52 |
| July | 1,062 | 487 | 710 | 43,660 | .740 | .853 |
| August | 487 | 398 | 448 | 27,550 | .467 | .538 |
| September | 457 | 339 | 394 | 23,440 | .410 | .457 |
| October | 398 | 368 | 374 | 23,000 | .390 | .450 |
| November | 398 | 368 | 370 | 22,020 | .385 | .430 |
| December 1-11 | 487 | 398 | 438 | 9,556 | .456 | .187 |
| The period | | | | 333,800 | | |

NOTE.—No estimate for ice period.

## SOUTH FORK OF SNAKE RIVER AT MORAN, WYO.

This station was established September 21, 1903, by Fred Stockton. It is located directly back of the post-office at Moran, Wyo., and about three-fourths of a mile below the outlet of Jackson Lake.

The channel is slightly curved for about 300 feet above the station. Below the station the channel is straight. At and above the station the current is smooth and has a well-distributed velocity. Below the station the current is broken by small bowlders. Both banks are high and are not liable to overflow. The right bank is wooded and the left bank is composed of gravel and is without trees. The bed of the stream is composed of firm gravel. There is but one channel at all stages.

Discharge measurements are made from a cable and car about 150 feet below the gage. The initial point for soundings is on the inner face of cable support on north side of river.

The gage is an inclined staff. During 1905 it was read once each day by Lizzie Roche and Maria Allen. The bench mark is a United States Geological Survey iron bench-mark post set about 30 feet from the gage; elevation, 10.77 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 452; 135, pp 179-180.
Discharge: 100, pp 452, 461; 135, p 180.
Discharge, monthly: 135, p 181.
Gage heights: 100, p 453; 135, p 180.
Rating table: 135, p 181.

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*Discharge measurements of South Fork of Snake River at Moran, Wyo., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 3 | E. C. La Rue | 202 | 910 | 3.60 | 4.10 | 3,276 |
| August 19 | Charles B. Smith | 196 | 496 | 1.69 | 1.75 | 837 |

*Daily gage height, in feet, of South Fork of Snake River at Moran, Wyo., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.9 | 1.3 | 1.2 | 1.25 | 1.65 | 4.05 | 4.2 | 2.35 | 1.6 | 1.2 | 0.9 | 0.9 |
| 2 | .9 | 1.3 | 1.2 | 1.25 | 1.65 | 4.2 | 4.15 | 2.35 | 1.6 | 1.2 | .9 | .9 |
| 3 | .9 | 1.3 | 1.15 | 1.25 | 1.65 | 4.3 | 4.1 | 2.3 | 1.55 | 1.2 | .9 | .9 |
| 4 | .9 | 1.3 | 1.15 | 1.25 | 1.65 | 4.35 | 4.1 | 2.3 | 1.5 | 1.15 | .9 | .9 |
| 5 | .9 | 1.3 | 1.15 | 1.25 | 1.7 | 4.4 | 3.95 | 2.25 | 1.5 | 1.15 | .9 | .9 |
| 6 | .9 | 1.3 | 1.15 | 1.25 | 1.7 | 4.45 | 3.95 | 2.25 | 1.5 | 1.15 | .9 | .9 |
| 7 | .9 | 1.25 | 1.15 | 1.25 | 1.7 | 4.6 | 3.9 | 2.25 | 1.5 | 1.15 | .9 | .9 |
| 8 | .9 | 1.25 | 1.15 | 1.25 | 1.75 | 5.0 | 3.8 | 2.25 | 1.45 | 1.15 | .9 | .9 |
| 9 | .9 | 1.25 | 1.15 | 1.25 | 1.8 | 5.1 | 3.7 | 2.2 | 1.45 | 1.1 | .9 | .9 |
| 10 | .9 | 1.25 | 1.15 | 1.25 | 1.85 | 5.15 | 3.55 | 2.2 | 1.45 | 1.1 | .9 | .9 |
| 11 | .9 | 1.2 | 1.15 | 1.25 | 1.9 | 5.05 | 3.5 | 2.2 | 1.45 | 1.1 | .9 | .9 |
| 12 | .9 | 1.2 | 1.15 | 1.25 | 1.9 | 5.05 | 3.4 | 2.2 | 1.4 | 1.1 | .9 | .9 |
| 13 | .9 | 1.2 | 1.15 | 1.25 | 1.9 | 5.0 | 3.35 | 2.0 | 1.35 | 1.1 | .9 | .9 |
| 14 | .9 | 1.2 | 1.15 | 1.25 | 1.95 | 5.05 | 3.3 | 1.9 | 1.3 | 1.1 | .9 | .9 |
| 15 | .9 | 1.2 | 1.15 | 1.3 | 1.95 | 5.15 | 3.25 | 1.85 | 1.3 | 1.1 | .9 | .9 |
| 16 | .9 | 1.2 | 1.15 | 1.3 | 1.95 | 5.1 | 3.25 | 1.85 | 1.25 | 1.1 | .9 | .9 |
| 17 | .9 | 1.2 | 1.15 | 1.35 | 2.0 | 5.1 | 3.25 | 1.85 | 1.25 | 1.1 | 1.0 | .9 |
| 18 | .9 | 1.2 | 1.15 | 1.35 | 2.1 | 5.05 | 3.15 | 1.75 | 1.25 | 1.1 | 1.0 | .9 |
| 19 | .9 | 1.2 | 1.15 | 1.4 | 2.3 | 5.0 | 3.1 | 1.75 | 1.2 | 1.2 | .9 | .9 |
| 20 | .9 | 1.2 | 1.15 | 1.4 | 2.3 | 4.85 | 3.05 | 1.75 | 1.2 | 1.1 | .9 | .9 |
| 21 | .9 | 1.2 | 1.2 | 1.4 | 2.3 | 4.65 | 2.9 | 1.75 | 1.2 | 1.1 | .9 | .9 |
| 22 | .9 | 1.2 | 1.2 | 1.45 | 2.4 | 4.5 | 2.9 | 1.75 | 1.2 | 1.1 | .9 | .9 |
| 23 | .9 | 1.2 | 1.25 | 1.45 | 2.45 | 4.45 | 2.8 | 1.7 | 1.2 | 1.1 | .9 | .9 |
| 24 | .9 | 1.2 | 1.25 | 1.45 | 2.5 | 4.35 | 2.7 | 1.7 | 1.2 | 1.1 | .9 | .9 |
| 25 | .9 | 1.2 | 1.25 | 1.5 | 2.55 | 4.35 | 2.6 | 1.7 | 1.2 | 1.05 | .9 | .9 |
| 26 | 1.0 | 1.2 | 1.25 | 1.55 | 2.6 | 4.35 | 2.55 | 1.7 | 1.2 | 1.05 | .9 | .9 |
| 27 | 1.0 | 1.2 | 1.25 | 1.55 | 2.7 | 4.35 | 2.55 | 1.75 | 1.25 | 1.05 | .9 | .9 |
| 28 | 1.1 | 1.2 | 1.25 | 1.6 | 3.0 | 4.35 | 2.55 | 1.7 | 1.25 | 1.0 | .9 | .9 |
| 29 | 1.2 | ..... | 1.25 | 1.6 | 3.05 | 4.3 | 2.45 | 1.7 | 1.25 | 1.0 | .9 | .9 |
| 30 | 1.2 | ..... | 1.25 | 1.65 | 3.35 | 4.25 | 2.45 | 1.65 | 1.25 | 1.0 | .9 | .9 |
| 31 | 1.3 | ..... | 1.25 | ..... | 3.8 | ..... | 2.4 | 1.65 | ..... | 1.0 | ..... | .9 |

NOTE.—No ice record.

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*Station rating table for South Fork of Snake River at Moran, Wyo., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.00 | 107 | 1.40 | 653 | 2.70 | 1,679 | 4.00 | 3,145 |
| 0.10 | 126 | 1.50 | 719 | 2.80 | 1,772 | 4.20 | 3,420 |
| 0.20 | 147 | 1.60 | 788 | 2.90 | 1,868 | 4.40 | 3,715 |
| 0.30 | 171 | 1.70 | 859 | 3.00 | 1,967 | 4.60 | 4,130 |
| 0.40 | 197 | 1.80 | 932 | 3.10 | 2,070 | 4.80 | 4,365 |
| 0.50 | 225 | 1.90 | 1,007 | 3.20 | 2,175 | 5.00 | 4,720 |
| 0.60 | 256 | 2.00 | 1,084 | 3.30 | 2,285 | 5.20 | 5,080 |
| 0.70 | 291 | 2.10 | 1,163 | 3.40 | 2,400 | 5.40 | 5,450 |
| 0.80 | 330 | 2.20 | 1,244 | 3.50 | 2,515 | 5.60 | 5,830 |
| 0.90 | 374 | 2.30 | 1,327 | 2.60 | 2,635 | 5.80 | 6,220 |
| 1.00 | 422 | 2.40 | 1,412 | 3.70 | 2,760 | 6.00 | 6,620 |
| 1.10 | 474 | 2.50 | 1,499 | 3.80 | 2,885 | 6.20 | 7,025 |
| 1.20 | 530 | 2.60 | 1,588 | 3.90 | 3,015 | 6.40 | 7,440 |
| 1.30 | 590 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on six discharge measurements made during 1903–1905. It is not well defined.

*Estimated monthly discharge of South Fork of Snake River at Moran, Wyo., for 1905.*

[Drainage area, 820 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 590 | 374 | 397 | 24,410 | 0.484 | 0.558 |
| February | 590 | 530 | 547 | 30,380 | .667 | .695 |
| March | 560 | 502 | 522 | 32,100 | .637 | .734 |
| April | 824 | 560 | 630 | 37,490 | .768 | .857 |
| May | 2,885 | 824 | 1,273 | 78,270 | 1.55 | 1.79 |
| June | 4,990 | 3,212 | 4,175 | 248,400 | 5.09 | 5.68 |
| July | 3,420 | 1,412 | 2,352 | 144,600 | 2.87 | 3.31 |
| August | 1,370 | 824 | 1,014 | 62,350 | 1.24 | 1.43 |
| September | 788 | 530 | 619 | 36,830 | .755 | .842 |
| October | 530 | 422 | 475 | 29,210 | .579 | .668 |
| November | 422 | 374 | 377 | 22,430 | .460 | .513 |
| December | 374 | 374 | 374 | 23,000 | .456 | .526 |
| The year | 4,990 | 374 | 1,063 | 769,500 | 1.30 | 17.60 |

## SOUTH FORK OF SNAKE RIVER NEAR LYON, IDAHO.

This station was established April 18, 1903, by N. S. Dils. It is located at the old site of Wedekind's ferry, between Lyon and Swan Valley at the upper end of Conant Valley. It is about 45 miles from Idaho Falls, Idaho.

The channel is straight above and below the station and the current is swift. The right bank is high and steep and will not overflow. At very high stages the left bank will overflow for a considerable distance and some water will pass around the station through a slough. The bed of the stream is composed of hard gravel and is free from vegetation and permanent.

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Discharge measurements are made from a cable and car at the old site of Wedekind's ferry. A tagged wire has been installed at the cable. The initial point for soundings is the pin in the top of a log of the crib cable support on the left bank.

The gage is an inclined staff, located on the north bank one-fourth mile below Carr's ferry and 1 mile above the cable. During 1905 the gage was read once each day by O. J. Carr. Bench marks were established as follows: (1) A United States Geological Survey iron bench-mark post set about 6 feet from the gage; elevation, 11.15 feet. (2) A United States Geological Survey aluminum tablet set in a rock on the left bank about 100 feet above Carr's ferry landing and about 6 feet above high-water mark; elevation, 10.44 feet. This bench mark is for use in high water when ferry service is discontinued. Elevations refer to the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 449–450; 135, p 182.
Discharge: 100, p 450; 135, p 183.
Discharge, monthly: 100, p 452; 135, p 184.
Gage heights: 100, pp 450–451; 135, p 183.
Rating table: 100, p 451; 135, p 184.

*Discharge measurements of South Fork of Snake River near Lyon, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 15 | E. C. La Rue | 260 | 1,500 | 2.37 | 1.85 | 3,558 |
| May 14 | do | 265 | 1,642 | 3.09 | 2.60 | 5,074 |
| June 25 | do | 283 | 2,063 | 5.73 | 4.85 | 11,810 |
| June 26 | do | 283 | 2,063 | 5.88 | 4.90 | 12,230 |
| July 14 | do | 269 | 1,729 | 4.53 | 3.70 | 7,845 |
| September 9 | do | 258 | 1,341 | 2.23 | 1.50 | 2,989 |
| November 15 | do | 251 | 1,275 | 1.76 | .93 | 2,236 |

*Daily gage height, in feet, of South Fork of Snake River near Lyon, Idaho, for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.3 | 2.85 | 5.0 | 4.75 | 2.5 | 1.7 | 1.5 | 1.15 | 0.85 |
| 2 | ..... | 1.3 | 2.9 | 5.3 | 4.7 | 2.45 | 1.65 | 1.45 | 1.15 | .8 |
| 3 | ..... | 1.3 | 3.1 | 5.5 | 4.5 | 2.35 | 1.6 | 1.4 | 1.15 | .9 |
| 4 | ..... | 1.3 | 3.05 | 5.8 | 4.45 | 2.35 | 1.65 | 1.35 | 1.15 | .9 |
| 5 | ..... | 1.3 | 2.8 | 5.9 | 4.4 | 2.3 | 1.6 | 1.35 | 1.15 | .9 |
| 6 | ..... | 1.35 | 2.7 | 5.7 | 4.3 | 2.3 | 1.6 | 1.3 | 1.15 | .7 |
| 7 | ..... | 1.5 | 2.7 | 5.35 | 4.25 | 2.25 | 1.55 | 1.3 | 1.1 | .7 |
| 8 | ..... | 1.8 | 2.8 | 5.7 | 4.2 | 2.2 | 1.55 | 1.3 | 1.1 | .85 |
| 9 | ..... | 1.9 | 3.0 | 6.1 | 4.15 | 2.1 | 1.5 | 1.3 | 1.1 | .8 |
| 10 | ..... | 2.0 | 2.85 | 6.0 | 4.05 | 2.1 | 1.5 | 1.3 | 1.05 | .6 |
| 11 | ..... | 1.8 | 2.7 | 5.6 | 4.0 | 2.05 | 1.5 | 1.3 | .95 | .6 |
| 12 | ..... | 1.7 | 2.7 | 5.4 | 3.9 | 2.05 | 1.45 | 1.3 | .95 | .6 |
| 13 | ..... | 1.75 | 2.6 | 5.55 | 3.85 | 2.05 | 1.45 | 1.3 | 1.0 | .5 |
| 14 | ..... | 1.9 | 2.6 | 5.85 | 3.75 | 2.05 | 1.4 | 1.25 | 1.05 | ..... |
| 15 | 1.35 | 1.8 | 2.65 | 5.95 | 3.7 | 2.0 | 1.4 | 1.25 | 1.0 | ..... |
| 16 | 1.35 | 1.9 | 2.75 | 5.9 | 3.65 | 1.9 | 1.35 | 1.25 | 1.05 | ..... |
| 17 | 1.4 | 1.9 | 3.05 | 5.65 | 3.5 | 1.85 | 1.35 | 1.25 | .95 | ..... |
| 18 | 1.45 | 1.85 | 3.55 | 5.5 | 3.35 | 1.8 | 1.35 | 1.3 | .95 | ..... |
| 19 | 1.45 | 1.9 | 3.7 | 5.1 | 3.25 | 1.8 | 1.3 | 1.25 | .95 | ..... |
| 20 | 1.45 | 2.1 | 3.7 | 4.85 | 3.2 | 1.75 | 1.3 | 1.2 | .9 | ..... |
| 21 | 1.45 | 2.15 | 3.9 | 4.7 | 3.15 | 1.7 | 1.3 | 1.2 | .9 | ..... |

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*Daily gage height, in feet, of South Fork of Snake River near Lyon, Idaho, for 1905*—Continued.

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 1.4 | 2.2 | 3.85 | 4.7 | 3.1 | 1.7 | 1.3 | 1.2 | 0.95 | ..... |
| 23 | 1.35 | 2.25 | 3.8 | 4.9 | 2.95 | 1.75 | 1.25 | 1.2 | .95 | ..... |
| 24 | 1.35 | 2.4 | 3.75 | 4.85 | 2.9 | 1.75 | 1.3 | 1.2 | .95 | ..... |
| 25 | 1.3 | 2.5 | 3.75 | 4.85 | 2.85 | 1.75 | 1.35 | 1.2 | .95 | ..... |
| 26 | 1.3 | 2.7 | 3.95 | 4.9 | 2.8 | 1.8 | 1.3 | 1.2 | .95 | ..... |
| 27 | 1.45 | 2.8 | 4.2 | 5.1 | 2.75 | 1.75 | 1.3 | 1.25 | .95 | ..... |
| 28 | 1.4 | 2.65 | 4.6 | 5.15 | 2.65 | 1.75 | 1.3 | 1.25 | .95 | ..... |
| 29 | 1.35 | 2.5 | 4.65 | 5.05 | 2.6 | 1.75 | 1.35 | 1.2 | .9 | ..... |
| 30 | 1.35 | 2.5 | 4.6 | 4.85 | 2.5 | 1.75 | 1.5 | 1.2 | .85 | ..... |
| 31 | 1.35 | ..... | 4.7 | ..... | 2.5 | 1.75 | ..... | 1.15 | ..... | ..... |

NOTE.—River gorged with ice December 14–31.

*Station rating table for South Fork of Snake River near Lyon, Idaho, from March 15 to December 13, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.50 | 1,800 | 1.70 | 3,320 | 2.90 | 5,750 | 4.00 | 8,760 |
| 0.60 | 1,900 | 1.80 | 3,495 | 3.00 | 5,980 | 4.20 | 9,420 |
| 0.70 | 2,005 | 1.90 | 3,680 | 3.10 | 6,220 | 4.40 | 10,150 |
| 0.80 | 2,115 | 2.00 | 3,870 | 3.20 | 6,470 | 4.60 | 10,920 |
| 0.90 | 2,225 | 2.10 | 4,065 | 3.30 | 6,730 | 4.80 | 11,710 |
| 1.00 | 2,340 | 2.20 | 4,265 | 3.40 | 7,000 | 5.00 | 12,520 |
| 1.10 | 2,460 | 2.30 | 4,465 | 3.50 | 7,280 | 5.20 | 13,370 |
| 1.20 | 2,585 | 2.40 | 4,670 | 3.60 | 7,560 | 5.40 | 14,290 |
| 1.30 | 2,715 | 2.50 | 4,880 | 3.70 | 7,850 | 5.60 | 15,270 |
| 1.40 | 2,855 | 2.60 | 5,090 | 3.80 | 8,150 | 5.80 | 16,280 |
| 1.50 | 3,000 | 2.70 | 5,310 | 3.90 | 8,450 | 6.00 | 17,320 |
| 1.60 | 3,155 | 2.80 | 5,530 | | | | |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1903–1905. It is well defined.

*Estimated monthly discharge of South Fork Snake River near Lyon, Idaho, for 1905.*

[Drainage area, 5,480 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| March 15–31 | 2,928 | 2,715 | 2,831 | 95,460 | 0.517 | 0.327 |
| April | 5,530 | 2,715 | 3,821 | 227,400 | .697 | .778 |
| May | 11,310 | 5,090 | 7,124 | 438,000 | 1.30 | 1.50 |
| June | 17,850 | 11,310 | 14,220 | 846,200 | 2.59 | 2.89 |
| July | 11,510 | 4,880 | 7,675 | 471,900 | 1.40 | 1.61 |
| August | 4,880 | 3,320 | 3,848 | 236,600 | .702 | .809 |
| September | 3,320 | 2,650 | 2,900 | 172,600 | .529 | .590 |
| October | 3,000 | 2,522 | 2,681 | 164,800 | .489 | .564 |
| November | 2,522 | 2,170 | 2,354 | 140,100 | .430 | .480 |
| December 1–13 | 2,225 | 1,800 | 2,058 | 53,070 | .376 | .182 |
| The period | ..... | ..... | ..... | 2,846,000 | ..... | ..... |



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## BLACKFOOT RIVER NEAR PRESTO, IDAHO.

This station was established April 17, 1903, by N. S. Dils. It is located on the ranch of James Just, 2 miles west of Presto and about 15 miles from Blackfoot, Idaho.

The current is sluggish. The banks are high and wooded and will not overflow. The bed of the stream is composed of gravel and is free from vegetation and permanent.

Discharge measurements are made from a cable and car located about one-fourth mile below the gage. The initial point for soundings is a tag marked "I. P." fastened to the inner face of the cable support on the west bank.

The gage is an inclined staff. During 1905 the gage was read once each day by James Just. The bench mark is a copper plug set in the corner stone of Mr. Just's brick house; elevation, 12.18 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 447; 135, p 186.
Discharge: 100, p 447; 135, p 186.
Gage heights: 100, p 448; 135, p 187.

*Discharge measurements of Blackfoot River near Presto, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 16 | E. C. La Rue | 54 | 197 | 2.23 | 2.20 | 439 |
| May 19 | do | 55 | 170 | 1.63 | 1.50 | 277 |
| June 8 | do | 52 | 145 | 1.41 | 1.00 | 205 |
| July 9 | do | 53 | 105 | .90 | .30 | 95 |

*Daily gage height, in feet, of Blackfoot River near Presto, Idaho, for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 1.4 | 2.1 | 1.2 | 0.5 | 0.1 | 0.25 | 0.55 | 0.7 | 0.5 |
| 2 | | 1.4 | 2.1 | 1.2 | .5 | .1 | .25 | .6 | .7 | .4 |
| 3 | | 1.45 | 2.35 | 1.15 | .4 | .1 | .2 | .6 | .65 | .6 |
| 4 | | 1.6 | 2.5 | 1.15 | .4 | .05 | .2 | .5 | .65 | .8 |
| 5 | 0.9 | 1.6 | 2.85 | 1.1 | .4 | .05 | .2 | .5 | .6 | .8 |
| 6 | .9 | 1.7 | 2.9 | 1.1 | .35 | .05 | .2 | .55 | .7 | .9 |
| 7 | 1.0 | 1.85 | 2.8 | 1.0 | .35 | .1 | .2 | .6 | .7 | .7 |
| 8 | 1.0 | 2.1 | 2.55 | 1.0 | .3 | .1 | .2 | .6 | .7 | .7 |
| 9 | 1.0 | 2.25 | 2.25 | 1.0 | .3 | .1 | .2 | .5 | .7 | .8 |
| 10 | .9 | 2.2 | 2.1 | .9 | .3 | .1 | .2 | .6 | .6 | .8 |
| 11 | .8 | 2.2 | 2.15 | .9 | .3 | .15 | .2 | .6 | .6 | .75 |
| 12 | 1.0 | 2.1 | 2.1 | .9 | .3 | .15 | .2 | .6 | .5 | .8 |
| 13 | .9 | 2.0 | 2.05 | 1.0 | .25 | .15 | .2 | .6 | .5 | .8 |
| 14 | 1.05 | 2.1 | 2.0 | 1.0 | .25 | .15 | .2 | .6 | .6 | .9 |
| 15 | 1.2 | 2.1 | 1.9 | 1.0 | .25 | .15 | .2 | .55 | .6 | .95 |
| 16 | 1.3 | 2.15 | 1.7 | 1.0 | .25 | .15 | .2 | .6 | .65 | 1.0 |
| 17 | 1.3 | 2.25 | 1.65 | .9 | .2 | .2 | .2 | .6 | .7 | 1.0 |
| 18 | 1.45 | 2.2 | 1.45 | .8 | .2 | .2 | .2 | .6 | .7 | 1.0 |
| 19 | 1.7 | 2.3 | 1.5 | .8 | .2 | .2 | .25 | .65 | .7 | .8 |
| 20 | 1.6 | 2.3 | 1.5 | .8 | .2 | .2 | .25 | .65 | .7 | .7 |
| 21 | 1.6 | 2.4 | 1.5 | .8 | .3 | .2 | .25 | .65 | .6 | .9 |
| 22 | 1.65 | 2.5 | 1.5 | .8 | .3 | .2 | .25 | .65 | .7 | .9 |
| 23 | 1.5 | 2.5 | 1.5 | .8 | .2 | .25 | .3 | .7 | .75 | 1.0 |
| 24 | 1.5 | 2.4 | 1.45 | .8 | .2 | 2.65 | .3 | .7 | .75 | 1.05 |

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*Daily gage height, in feet, of Blackfoot River near Presto, Idaho, for 1905*—Continued.

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 1.4 | 2.4 | 1.45 | 0.7 | 0.2 | 1.3 | 0.3 | 0.7 | 0.8 | 1.0 |
| 26 | 1.55 | 2.4 | 1.4 | .7 | .2 | .5 | .35 | .7 | .8 | 1.0 |
| 27 | 1.7 | 2.4 | 1.4 | .65 | .2 | .4 | .35 | .7 | .7 | 1.1 |
| 28 | 1.7 | 2.4 | 1.3 | .65 | .2 | .3 | .4 | .7 | .7 | 1.0 |
| 29 | 1.7 | 2.4 | 1.3 | .65 | .2 | .3 | .5 | .7 | .6 | 1.0 |
| 30 | 1.75 | 2.25 | 1.3 | .65 | .15 | .3 | .5 | .7 | .6 | 1.0 |
| 31 | 1.6 | ..... | 1.25 | ..... | .15 | .25 | ..... | .7 | ..... | 1.1 |

NOTE.—No ice record.

*Station rating table for Blackfoot River near Presto, Idaho, from January 1, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.00 | 59 | 1.40 | 269 | 2.80 | 577 | 4.40 | 1,155 |
| .10 | 70 | 1.50 | 287 | 2.90 | 606 | 4.60 | 1,240 |
| .20 | 82 | 1.60 | 306 | 3.00 | 636 | 4.80 | 1,340 |
| .30 | 94 | 1.70 | 325 | 3.10 | 668 | 5.00 | 1,440 |
| .40 | 107 | 1.80 | 345 | 3.20 | 701 | 5.20 | 1,540 |
| .50 | 121 | 1.90 | 365 | 3.30 | 735 | 5.40 | 1,640 |
| .60 | 135 | 2.00 | 386 | 3.40 | 770 | 5.60 | 1,760 |
| .70 | 150 | 2.10 | 407 | 3.50 | 805 | 5.80 | 1,880 |
| .80 | 166 | 2.20 | 429 | 3.60 | 840 | 6.00 | 2,000 |
| .90 | 182 | 2.30 | 451 | 3.70 | 875 | 6.20 | 2,120 |
| 1.00 | 199 | 2.40 | 474 | 3.80 | 915 | 6.40 | 2,240 |
| 1.10 | 216 | 2.50 | 498 | 3.90 | 955 | 6.60 | 2,380 |
| 1.20 | 233 | 2.60 | 523 | 4.00 | 995 | 6.80 | 2,520 |
| 1.30 | 251 | 2.70 | 549 | 4.20 | 1,075 | 7.00 | 2,660 |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904–5. It is well defined between gage heights 0.3 foot and 2.7 feet.

*Estimated monthly discharge of Blackfoot River near Presto, Idaho, for 1904 and 1905.*

[Drainage area, 1,016 square miles.]

| Month | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| 1904. | | | | | | |
| June | 975 | 233 | 536 | 31,890 | 0.528 | 0.589 |
| July | 216 | 150 | 179 | 11,010 | .176 | .203 |
| August | 182 | 150 | 161 | 9,900 | .158 | .182 |
| September | 216 | 182 | 198 | 11,780 | .195 | .218 |
| October | 269 | 216 | 251 | 15,430 | .247 | .285 |
| November | 269 | 216 | 230 | 13,680 | .226 | .252 |
| December 1–10 | 269 | 216 | 238 | 4,721 | .234 | .087 |
| The period | ..... | ..... | ..... | 98,410 | ..... | ..... |

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*Estimated monthly discharge of Blackfoot River near Presto, Idaho, for 1904 and 1905*—Continued.

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| 1905. | | | | | | |
| March 5–31 | 335 | 166 | 256 | 13,710 | 0.252 | 0.253 |
| April | 498 | 269 | 412 | 24,520 | .406 | .453 |
| May | 606 | 242 | 368 | 22,630 | .362 | .417 |
| June | 233 | 142 | 183 | 10,890 | .180 | .201 |
| July | 121 | 76 | 91.2 | 5,608 | .090 | .104 |
| August | 536 | 64 | 100 | 6,149 | .098 | .113 |
| September | 121 | 82 | 89.0 | 5,296 | .088 | .098 |
| October | 150 | 121 | 138 | 8,485 | .136 | .157 |
| November | 166 | 121 | 145 | 8,628 | .143 | .160 |
| December | 216 | 107 | 177 | 10,880 | .174 | .201 |
| The period | | | | 116,800 | | |

NOTE.—No estimate for ice period.

## BIG LOST RIVER NEAR MACKAY, IDAHO.

This station was established November 12, 1903, by Fred Stockton. It is located 3¼ miles above Mackay, Idaho, above "The Narrows."

The channel of the stream is slightly curved both above and below the station. The south bank is steep and high and does not overflow; the north bank slopes gradually and will overflow during high water.

Discharge measurements are made from a cable. The initial point for soundings is a tin tag marked "I. P." on the inside face of cable support on north bank of stream.

A permanent gage was set November 3, 1904, at "The Narrows," about a mile below the cable. It is located back of Joseph Cresto's house and consists of a post set vertically and securely anchored. During 1905 the gage was read once each day by Joseph Cresto. The bench mark is a United States Geological Survey iron bench-mark post set about 15 feet from the gage; elevation, 9.83 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 447; 135, pp 187–188.
Discharge: 135, p 188.
Discharge, monthly: 135, p 189.
Gage heights: 100, p 447; 135, p 188.
Rating table: 135, p 189.

*Discharge measurements of Big Lost River near Mackay, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 18 | E. C. La Rue | 37 | 74 | 1.84 | 2.50 | 136 |
| May 15 | do | 37 | 72 | 1.72 | 2.45 | 124 |
| June 10 | do | 51 | 193 | 5.12 | 5.15 | 987 |
| July 11 | do | 44 | 151 | 4.17 | 4.10 | 629 |
| September 21 | do | 37 | 89 | 1.75 | 2.65 | 156 |
| November 22 | do | 38 | 93 | 1.89 | 2.80 | 176 |

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*Daily gage height, in feet, of Big Lost River near Mackay, Idaho, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.7 | 2.65 | 2.6 | 2.6 | 2.5 | 3.9 | 4.5 | 3.15 | 2.75 | 2.7 | 2.8 | 2.8 |
| 2 | 2.7 | 2.65 | 2.6 | 2.6 | 2.5 | 4.3 | 4.6 | 3.1 | 2.75 | 2.7 | 2.8 | 2.8 |
| 3 | 2.7 | 2.65 | 2.6 | 2.6 | 2.5 | 4.5 | 4.4 | 3.1 | 2.75 | 2.7 | 2.8 | 2.8 |
| 4 | 2.7 | 2.65 | 2.6 | 2.55 | 2.5 | 4.5 | 4.35 | 3.1 | 2.75 | 2.7 | 2.8 | 2.8 |
| 5 | 2.7 | 2.65 | 2.6 | 2.55 | 2.5 | 4.8 | 4.3 | 3.05 | 2.7 | 2.7 | 2.8 | 2.75 |
| 6 | 2.7 | 2.65 | 2.6 | 2.55 | 2.5 | 4.85 | 4.3 | 3.05 | 2.7 | 2.7 | 2.8 | 2.75 |
| 7 | 2.7 | 2.65 | 2.6 | 2.55 | 2.5 | 4.6 | 4.3 | 3.05 | 2.7 | 2.7 | 2.8 | 2.75 |
| 8 | 2.7 | 2.65 | 2.6 | 2.55 | 2.5 | 4.5 | 4.3 | 3.05 | 2.7 | 2.75 | 2.8 | 2.75 |
| 9 | 2.7 | 2.65 | 2.6 | 2.55 | 2.5 | 5.0 | 4.25 | 3.05 | 2.7 | 2.75 | 2.8 | 2.75 |
| 10 | 2.7 | 2.65 | 2.6 | 2.55 | 2.5 | 5.15 | 4.25 | 3.0 | 2.7 | 2.75 | 2.8 | 2.75 |
| 11 | 2.7 | 2.65 | 2.6 | 2.55 | 2.5 | 4.8 | 4.1 | 3.0 | 2.7 | 2.75 | 2.8 | 2.75 |
| 12 | 2.7 | 2.65 | 2.6 | 2.5 | 2.5 | 5.2 | 4.05 | 3.0 | 2.7 | 2.75 | 2.8 | 2.75 |
| 13 | 2.7 | 2.65 | 2.6 | 2.5 | 2.5 | 5.35 | 4.0 | 2.95 | 2.7 | 2.75 | 2.8 | 2.75 |
| 14 | 2.7 | 2.65 | 2.6 | 2.5 | 2.45 | 5.4 | 3.85 | 2.95 | 2.7 | 2.75 | 2.8 | 2.75 |
| 15 | 2.7 | 2.65 | 2.6 | 2.5 | 2.45 | 5.2 | 3.7 | 2.9 | 2.7 | 2.75 | 2.8 | 2.75 |
| 16 | 2.7 | 2.65 | 2.6 | 2.5 | 2.45 | 4.95 | 3.7 | 2.9 | 2.7 | 2.75 | 2.8 | 2.75 |
| 17 | 2.7 | 2.65 | 2.6 | 2.5 | 2.45 | 4.95 | 3.6 | 2.9 | 2.7 | 2.75 | 2.8 | 2.75 |
| 18 | 2.7 | 2.65 | 2.6 | 2.5 | 2.45 | 4.9 | 3.55 | 2.9 | 2.7 | 2.75 | 2.8 | 2.75 |
| 19 | 2.7 | 2.65 | 2.6 | 2.5 | 2.45 | 4.5 | 3.5 | 2.9 | 2.65 | 2.8 | 2.8 | 2.75 |
| 20 | 2.7 | 2.65 | 2.6 | 2.5 | 2.45 | 4.5 | 3.45 | 2.9 | 2.65 | 2.8 | 2.8 | 2.75 |
| 21 | 2.7 | 2.6 | 2.6 | 2.5 | 2.45 | 4.5 | 3.4 | 2.9 | 2.65 | 2.8 | 2.8 | 2.75 |
| 22 | 2.7 | 2.6 | 2.6 | 2.5 | 2.5 | 4.8 | 3.4 | 2.85 | 2.65 | 2.8 | 2.8 | 2.75 |
| 23 | 2.7 | 2.6 | 2.6 | 2.5 | 2.55 | 5.0 | 3.45 | 2.85 | 2.65 | 2.8 | 2.8 | 2.75 |
| 24 | 2.7 | 2.6 | 2.6 | 2.5 | 2.55 | 4.9 | 3.4 | 2.85 | 2.65 | 2.8 | 2.8 | 2.75 |
| 25 | 2.65 | 2.6 | 2.6 | 2.5 | 2.55 | 4.75 | 3.4 | 2.8 | 2.65 | 2.8 | 2.8 | 2.7 |
| 26 | 2.65 | 2.6 | 2.6 | 2.5 | 2.55 | 4.6 | 3.35 | 2.8 | 2.65 | 2.8 | 2.8 | 2.7 |
| 27 | 2.65 | 2.6 | 2.6 | 2.5 | 2.55 | 4.6 | 3.3 | 2.8 | 2.65 | 2.8 | 2.8 | 2.7 |
| 28 | 2.65 | 2.6 | 2.6 | 2.5 | 2.65 | 4.5 | 3.3 | 2.8 | 2.65 | 2.8 | 2.8 | 2.7 |
| 29 | 2.65 | ..... | 2.6 | 2.5 | 2.9 | 4.4 | 3.3 | 2.8 | 2.65 | 2.8 | 2.8 | 2.7 |
| 30 | 2.65 | ..... | 2.6 | 2.5 | 3.1 | 4.4 | 3.25 | 2.75 | 2.65 | 2.8 | 2.8 | 2.7 |
| 31 | 2.65 | ..... | 2.6 | ..... | 3.3 | ..... | 3.2 | 2.75 | ..... | 2.8 | ..... | 2.7 |

NOTE.—No ice record.

*Station rating table for Big Lost River near Mackay, Idaho, from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.50 | 129 | 3.30 | 313 | 4.10 | 592 | 4.80 | 868 |
| 2.60 | 145 | 3.40 | 345 | 4.20 | 630 | 4.90 | 909 |
| 2.70 | 163 | 3.50 | 378 | 4.30 | 669 | 5.00 | 950 |
| 2.80 | 183 | 3.60 | 412 | 4.40 | 708 | 5.10 | 992 |
| 2.90 | 205 | 3.70 | 447 | 4.50 | 748 | 5.20 | 1,034 |
| 3.00 | 229 | 3.80 | 482 | 4.60 | 788 | 5.30 | 1,077 |
| 3.10 | 255 | 3.90 | 518 | 4.70 | 828 | 5.40 | 1,120 |
| 3.20 | 283 | 4.00 | 555 | | | | |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904–5. It is well defined.

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*Estimated monthly discharge of Big Lost River near Mackay, Idaho, for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 163 | 154 | 161 | 9,900 |
| February | 154 | 145 | 151 | 8,386 |
| March | 145 | 145 | 145 | 8,914 |
| April | 145 | 129 | 133 | 7,914 |
| May | 313 | 122 | 142 | 8,731 |
| June | 1,120 | 518 | 847 | 50,400 |
| July | 788 | 283 | 489 | 30,070 |
| August | 269 | 173 | 214 | 13,160 |
| September | 173 | 154 | 161 | 9,580 |
| October | 183 | 163 | 175 | 10,760 |
| November | 183 | 183 | 183 | 10,890 |
| December | 183 | 163 | 172 | 10,580 |
| The year | 1,120 | 122 | 248 | 179,300 |

## BIG LOST RIVER NEAR CHILLY, IDAHO.

This station was established April 25, 1904, by Fred Stockton. It is located at Frank Uehren's ranch, about 25 miles upstream from Mackay, 7 miles from Chilly, and about 3 miles above Kinickinick Ppint. This ranch is the last one on the east bank.

The channel is straight for about 200 feet above and 250 feet below the station. Both banks are low and liable to overflow during high water. The stream has but one channel during all stages.

Discharge measurements are made from a cable and car located about three-fourths of a mile above Mr. Uehren's house. The initial point for soundings is a tin tag marked "I. P." on the face of the cable support on east side.

The gage is a vertical staff located about one-fourth mile from the ranch house. During 1905 the gage was read once each day by Frank Uehren and J. S. Fullmer. The bench mark is a United States Geological Survey iron bench-mark post about 10 feet from the gage; elevation, 7.49 feet above the datum of the gage.

A description of this station, with gage heights, discharge data, and rating table is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 190–192.

*Discharge measurements of Big Lost River near Chilly, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 18 | E. C. La Rue | 81 | 109 | 1.01 | 1.57 | 110 |
| May 16 | do | 82 | 142 | 1.53 | 2.10 | 217 |
| June 11 | do | 84 | 247 | 4.08 | 4.25 | 1,007 |
| July 12 | do | 83 | 221 | 3.04 | 3.50 | 671 |
| September 22 | do | 82 | 103 | .85 | 1.45 | 88 |
| November 21 | do | 81 | 101 | .87 | 1.45 | 88 |

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*Daily gage height, in feet, of Big Lost River near Chilly, Idaho, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.3 | 1.4 | 1.3 | 1.4 | 1.9 | 4.55 | 3.65 | 2.3 | 1.9 | 1.7 | 1.5 | 1.5 |
| 2 | 1.3 | 1.4 | 1.3 | 1.5 | 1.9 | 4.7 | 3.65 | 2.4 | 1.85 | 1.7 | 1.5 | 1.5 |
| 3 | 1.4 | 1.4 | 1.3 | 1.5 | 1.9 | 4.5 | 3.65 | 2.4 | 1.8 | 1.7 | 1.5 | 1.7 |
| 4 | 1.35 | 1.45 | 1.4 | 1.4 | 1.8 | 4.1 | 3.9 | 2.3 | 1.8 | 1.65 | 1.5 | 1.5 |
| 5 | 1.3 | 1.4 | 1.4 | 1.5 | 1.8 | 4.5 | 3.7 | 2.4 | 1.8 | 1.65 | 1.5 | 1.5 |
| 6 | 1.3 | 1.4 | 1.4 | 1.6 | 1.8 | 3.95 | 3.55 | 2.3 | 1.8 | 1.65 | 1.5 | 1.4 |
| 7 | 1.4 | 1.4 | 1.4 | 1.6 | 1.8 | 4.0 | 3.8 | 2.3 | 1.75 | 1.65 | 1.5 | 1.4 |
| 8 | 1.3 | 1.4 | 1.4 | 1.6 | 2.0 | 4.5 | 3.5 | 2.3 | 1.75 | 1.65 | 1.5 | 1.35 |
| 9 | 1.3 | 1.35 | 1.4 | 1.6 | 2.0 | 4.6 | 3.45 | 2.2 | 1.75 | 1.65 | 1.5 | 1.3 |
| 10 | 1.35 | 1.5 | 1.4 | 1.6 | 2.0 | 4.1 | 3.55 | 2.2 | 1.75 | 1.7 | 1.5 | 1.3 |
| 11 | 1.5 | 1.65 | 1.4 | 1.5 | 1.9 | 4.2 | 3.55 | 2.15 | 1.7 | 1.7 | 1.6 | 1.3 |
| 12 | 1.5 | 1.8 | 1.5 | 1.6 | 1.9 | 4.9 | 3.5 | 2.15 | 1.7 | 1.65 | 1.65 | 1.3 |
| 13 | 1.5 | 1.6 | 1.5 | 1.6 | 1.9 | 4.9 | 3.4 | 2.05 | 1.7 | 1.65 | 1.65 | 1.3 |
| 14 | 1.5 | 1.6 | 1.5 | 1.6 | 1.9 | 4.9 | 3.1 | 2.05 | 1.7 | 1.65 | 1.7 | 1.3 |
| 15 | 1.4 | 1.5 | 1.5 | 1.6 | 1.9 | 4.75 | 3.1 | 2.0 | 1.7 | 1.65 | 1.8 | 1.35 |
| 16 | 1.4 | 1.5 | 1.5 | 1.7 | 2.0 | 4.1 | 3.0 | 2.0 | 1.7 | 1.65 | 2.0 | 1.35 |
| 17 | 1.4 | 1.5 | 1.5 | 1.7 | 2.65 | 3.9 | 3.0 | 2.0 | 1.7 | 1.6 | 1.9 | 1.3 |
| 18 | 1.4 | 1.6 | 1.5 | 1.7 | 2.95 | 3.8 | 2.7 | 1.9 | 1.7 | 1.6 | 1.9 | 1.35 |
| 19 | ..... | 1.7 | 1.4 | 1.7 | 2.95 | 3.45 | 2.75 | 1.9 | 1.7 | 1.6 | 1.9 | 1.35 |
| 20 | ..... | 1.5 | 1.4 | 1.7 | 3.1 | 3.5 | 2.8 | 1.9 | 1.7 | 1.6 | 1.9 | 1.4 |
| 21 | 1.5 | 1.5 | 1.4 | 1.7 | 3.05 | 3.95 | 2.7 | 1.9 | 1.65 | 1.6 | 1.45 | 1.35 |
| 22 | 1.4 | 1.4 | 1.4 | 1.7 | 2.75 | 4.15 | 2.75 | 1.9 | 1.65 | 1.6 | 1.45 | 1.35 |
| 23 | 1.4 | 1.4 | 1.4 | 1.7 | 2.65 | 4.2 | 2.7 | 1.9 | 1.65 | 1.6 | 1.45 | 1.3 |
| 24 | 1.4 | 1.4 | 1.4 | 1.8 | 2.5 | 3.95 | 2.6 | 1.85 | 1.7 | 1.5 | 1.45 | 1.3 |
| 25 | 1.4 | 1.5 | 1.4 | 1.8 | 2.7 | 3.7 | 2.4 | 1.9 | 1.7 | 1.5 | 1.5 | 1.35 |
| 26 | 1.4 | 1.3 | 1.4 | 1.9 | 2.85 | 3.9 | 2.5 | 1.9 | 1.65 | 1.5 | 1.5 | 1.35 |
| 27 | 1.4 | 1.3 | 1.4 | 1.9 | 3.15 | 3.9 | 2.55 | 1.9 | 1.65 | 1.5 | 1.5 | 1.35 |
| 28 | 1.4 | 1.3 | 1.4 | 1.9 | 3.45 | 3.6 | 2.5 | 1.9 | 1.65 | 1.5 | 1.5 | 1.35 |
| 29 | 1.4 | ..... | 1.5 | 1.9 | 3.25 | 3.7 | 2.3 | 1.85 | 1.65 | 1.5 | 1.5 | 1.35 |
| 30 | 1.4 | ..... | 1.5 | 1.9 | 3.4 | 3.7 | 2.3 | 1.8 | 1.7 | 1.5 | 1.5 | 1.4 |
| 31 | 1.35 | ..... | 1.4 | ..... | 3.7 | ..... | 2.3 | 1.85 | ..... | 1.5 | ..... | 1.35 |

NOTE.—No ice record.

*Station rating table for Big Lost River near Chilly, Idaho, from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.30 | 65 | 2.30 | 267 | 3.20 | 553 | 4.10 | 937 |
| 1.40 | 80 | 2.40 | 293 | 3.30 | 591 | 4.20 | 985 |
| 1.50 | 96 | 2.50 | 320 | 3.40 | 630 | 4.30 | 1,034 |
| 1.60 | 114 | 2.60 | 349 | 3.50 | 670 | 4.40 | 1,084 |
| 1.70 | 133 | 2.70 | 379 | 3.60 | 712 | 4.50 | 1,135 |
| 1.80 | 153 | 2.80 | 411 | 3.70 | 755 | 4.60 | 1,188 |
| 1.90 | 174 | 2.90 | 445 | 3.80 | 799 | 4.70 | 1,242 |
| 2.00 | 195 | 3.00 | 480 | 3.90 | 844 | 4.80 | 1,298 |
| 2.10 | 218 | 3.10 | 516 | 4.00 | 890 | 4.90 | 1,355 |
| 2.20 | 242 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on six discharge measurements made during 1905 and one during 1904. It is well defined.

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*Estimated monthly discharge of Big Lost River near Chilly, Idaho, for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 96 | 65 | 79.4 | 4,882 |
| February | 153 | 65 | 92.1 | 5,115 |
| March | 96 | 65 | 86.3 | 5,306 |
| April | 174 | 80 | 127 | 7,557 |
| May | 755 | 153 | 326 | 20,040 |
| June | 1,355 | 650 | 973 | 57,900 |
| July | 844 | 267 | 517 | 31,790 |
| August | 293 | 153 | 211 | 12,970 |
| September | 174 | 124 | 137 | 8,152 |
| October | 133 | 96 | 116 | 7,132 |
| November | 195 | 88 | 114 | 6,783 |
| December | 133 | 65 | 75.6 | 4,648 |
| The year | 1,355 | 65 | 238 | 172,300 |

NOTE.—Missing gage heights interpolated.

## BIG WOOD RIVER NEAR GIMLET, IDAHO.

This station was established by Fred Stockton April 25, 1904, and was discontinued May 31, 1905. The station is located on a wagon bridge on the road from Hailey to Ketchum, near Gimlet, a small station on the Oregon Short Line Railroad, about 6 miles from Hailey and 6 miles from Ketchum. The wagon bridge is about 200 feet below the railroad bridge crossing Big Wood River.

The channel is straight for 250 feet above and 1,000 feet below the bridge. The banks are high and covered with brush and are not liable to overflow. The stream has but one channel in either high or low water.

Discharge measurements are made from the bridge. The initial point for soundings is a tag marked "I. P." nailed on the hand rail on the downstream side of the bridge.

The gage is a staff, spiked against a timber on the upstream side of the north abutment to the wagon bridge. During 1905 the gage was read once each day by A. C. Comstock. The bench mark is a United States Geological Survey iron bench-mark post set in the door-yard of the first ranch house above Gimlet; elevation, 5,544 feet above sea level and 15.09 feet above the datum of the gage.

A description of this station, with gage heights and discharge data, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 192–193.

*Discharge measurements of Big Wood River near Gimlet, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 22 | E. C. LaRue | 40 | 165 | 1.92 | 1.05 | 317 |
| May 22 | do | 40 | 178 | 2.84 | 1.60 | 505 |

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*Daily gage height, in feet, of Big Wood River near Gimlet, Idaho, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | Day. | Jan. | Feb. | Mar. | Apr. | May. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.6 | 0.6 | 0.55 | 0.6 | 1.05 | 17 | 0.6 | 0.6 | 0.7 | 0.9 | 1.35 |
| 2 | .6 | .6 | .55 | .65 | 1.05 | 18 | .6 | .6 | .7 | .9 | 1.5 |
| 3 | .6 | .6 | .5 | .7 | 1.0 | 19 | .6 | .6 | .7 | .9 | 1.7 |
| 4 | .6 | .6 | .55 | .7 | 1.0 | 20 | .6 | .6 | .7 | .95 | 1.8 |
| 5 | .6 | .6 | .55 | .8 | 1.0 | 21 | .6 | .6 | .7 | .95 | 1.7 |
| 6 | .6 | .6 | .6 | .95 | 1.0 | 22 | .6 | .6 | .7 | 1.0 | 1.6 |
| 7 | .6 | .6 | .6 | .95 | 1.05 | 23 | .6 | .6 | .7 | 1.0 | 1.6 |
| 8 | .6 | .6 | .6 | .95 | 1.1 | 24 | .6 | .6 | .7 | 1.0 | 1.65 |
| 9 | .6 | .6 | .65 | 1.0 | 1.1 | 25 | .6 | .6 | .7 | 1.0 | 1.7 |
| 10 | .6 | .6 | .65 | 1.0 | 1.05 | 26 | .6 | .6 | .7 | 1.1 | 1.8 |
| 11 | .6 | .6 | .65 | 1.0 | 1.05 | 27 | .6 | .6 | .7 | 1.1 | 1.75 |
| 12 | .6 | .6 | .65 | 1.0 | 1.05 | 28 | .6 | .6 | .7 | 1.1 | 1.6 |
| 13 | .6 | .6 | .65 | .95 | 1.05 | 29 | .6 | ..... | .65 | 1.1 | 1.7 |
| 14 | .6 | .6 | .7 | .95 | 1.1 | 30 | .6 | ..... | .6 | 1.1 | 1.7 |
| 15 | .6 | .6 | .7 | .95 | 1.2 | 31 | .6 | ..... | .6 | ..... | 1.75 |
| 16 | .6 | .6 | .7 | .95 | 1.2 | | | | | | |

NOTE.—No ice record.

## BIG WOOD RIVER NEAR SHOSHONE, IDAHO.

This station was established June 5, 1905, by E. C. La Rue. It is located at A. D. Silva's ranch, 1 mile below the steel wagon bridge and 7 miles northwest of Shoshone, Idaho, the nearest railway point. The water is sluggish during low stages, but rather swift during high water. Both banks are high and not liable to overflow. Measurements are made from a boat, held by a cable. The initial point for soundings is a post on the right bank which is used as a support for the tag wire. The gage is a vertical staff on the right bank, 100 yards below the cable. During 1905 the gage was read once each day by A. D. Silva. The bench mark is a standard United States Geological Survey iron post set about 3 feet from the southeast corner of Mr. Silva's house; elevation, 13.12 feet above the datum of the gage.

*Daily gage height, in feet, of Big Wood River near Shoshone, Idaho, for 1905.*

| Day. | June. | July. | Day. | June. | July. | Day. | June. | July. | Day. | June. | July. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 2.75 | 9 | 3.55 | 2.85 | 17 | 3.7 | 2.5 | 25 | 3.0 | 2.0 |
| 2 | ..... | 2.75 | 10 | 3.75 | 2.8 | 18 | 3.75 | 2.5 | 26 | 2.95 | 1.95 |
| 3 | ..... | 2.75 | 11 | 3.7 | 2.8 | 19 | 3.55 | 2.4 | 27 | 2.9 | 1.9 |
| 4 | ..... | 2.75 | 12 | 3.6 | 2.75 | 20 | 3.3 | 2.35 | 28 | 2.9 | (a) |
| 5 | 3.75 | 2.7 | 13 | 3.75 | 2.7 | 21 | 3.1 | 2.2 | 29 | 2.9 | ..... |
| 6 | 3.9 | 2.7 | 14 | 3.85 | 2.65 | 22 | 2.95 | 2.2 | 30 | 2.85 | ..... |
| 7 | 3.7 | 2.6 | 15 | 3.8 | 2.6 | 23 | 2.95 | 2.15 | | | |
| 8 | 3.5 | 2.5 | 16 | 3.8 | 2.55 | 24 | 3.0 | 2.1 | | | |

a River dry remainder of year.

## LITTLE WOOD RIVER NEAR CAREY, IDAHO.

This station was established April 28, 1904, by William G. Davies, and was discontinued May 31, 1905. The station is located 7 miles upstream from Carey on the Carey-Muldoon road, about one-half mile above the dam at the head of the east and west side canals, and above the slough or delta section of the river. It is 15 miles from Picabo, the nearest railroad point.

The channel is straight both above and below the station. The banks are high and clean,

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and not liable to overflow. The stream has one channel at both high and low water and its bed is smooth and clean.

Discharge measurements are made from a cable and car. The initial point for soundings is a tin tag marked "I. P." on an iron anchor set in a rock on the west bank.

The gage is a vertical staff bolted to a lava wall on the east bank of the river. During 1905 the gage was read once each day by Mrs. F. M. Ford. The bench mark is a United States Geological Survey aluminum bench mark tablet set 3 feet from the gage in solid lava; elevation, 6.00 feet above the datum of the gage.

A description of this station and gage height and discharge data are contained in Water Supply Paper No. 135, United States Geological Survey, pages 193–195.

*Discharge measurements of Little Wood River near Carey, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 23 | E. C. La Rue | 39 | 91 | 1.53 | 1.42 | 139 |
| May 23 | do | 42 | 100 | 1.84 | 1.65 | 184 |

*Daily gage height, in feet, of Little Wood River near Carey, Idaho, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | Day. | Jan. | Feb. | Mar. | Apr. | May. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 1.0 | 1.8 | 1.1 | 1.4 | 17 | 1.8 | 1.3 | 1.1 | 1.1 | 1.3 |
| 2 | 1.0 | 1.1 | 1.7 | 1.1 | 1.5 | 18 | 1.6 | 1.4 | 1.0 | 1.1 | 1.4 |
| 3 | 1.0 | 1.1 | 1.2 | 1.1 | 1.7 | 19 | 1.6 | 1.4 | 1.1 | 1.2 | 1.5 |
| 4 | 1.1 | 1.1 | 1.0 | 1.1 | 1.6 | 20 | 1.6 | 1.6 | 1.1 | 1.2 | 1.6 |
| 5 | 1.1 | 1.1 | 1.0 | 1.2 | 1.6 | 21 | 1.0 | 1.6 | 1.1 | 1.1 | 1.7 |
| 6 | 1.1 | 1.1 | 1.0 | 1.3 | 1.6 | 22 | 1.0 | 1.6 | 1.1 | 1.4 | 1.7 |
| 7 | 1.1 | 1.1 | 1.0 | 1.6 | 1.5 | 23 | 1.0 | 1.6 | 1.1 | 1.4 | 1.7 |
| 8 | 1.0 | 1.1 | 1.0 | 1.4 | 1.6 | 24 | 1.0 | 1.6 | 1.1 | 1.4 | 1.6 |
| 9 | 1.0 | 1.1 | 1.0 | 1.3 | 1.6 | 25 | 1.0 | 1.6 | 1.1 | 1.4 | 1.6 |
| 10 | 1.0 | 1.0 | 1.0 | 1.2 | 1.6 | 26 | 1.0 | 1.7 | 1.1 | 1.4 | 1.5 |
| 11 | 1.0 | 1.0 | 1.0 | 1.2 | 1.6 | 27 | 1.0 | 1.7 | 1.1 | 1.5 | 1.6 |
| 12 | 1.6 | 1.0 | 1.0 | 1.2 | 1.6 | 28 | 1.0 | 1.8 | 1.1 | 1.5 | 1.7 |
| 13 | 1.6 | 1.0 | 1.2 | 1.1 | 1.6 | 29 | .9 | ..... | 1.1 | 1.5 | 1.7 |
| 14 | 1.7 | 1.0 | 1.2 | 1.1 | 1.5 | 30 | .9 | ..... | 1.1 | 1.4 | 1.7 |
| 15 | 1.7 | 1.0 | 1.2 | 1.2 | 1.4 | 31 | .9 | ..... | 1.1 | ..... | 1.7 |
| 16 | 1.8 | 1.2 | 1.2 | 1.2 | 1.4 | | | | | | |

## SUCCOR CREEK NEAR HOMEDALE, IDAHO.

This station was established March 19, 1903, by N. S. Dils. It was originally located at a small truss bridge built to carry a flume, about one-half mile above the mouth of the river. The station was moved January 31, 1905, about half a mile upstream to a location 1 mile west of Homedale and about 17 miles from Caldwell, the nearest railroad station. It is near the Caldwell-Jordan Valley stage road, 1 mile west of Mussel's ferry on Snake River, one-fourth mile below the head of the lowest ditch on Succor Creek, and about three-fourths of a mile above the mouth of the creek.

The river channel is straight for about 200 feet above and below the station. The bed of the stream is gravelly and has one channel at all stages. The right bank is low, slopes uniformly, and may overflow during high water. The left bank is high and not liable to overflow.

Discharge measurements are made from a cable and car. The initial point for soundings is the inside face of the cable support on the left bank of the stream.

The gage is an inclined staff on the left bank of the stream, about one-third mile above the house of Mrs. Minnie Tracy, who during 1905 read the gage once each day. The bench

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mark is a United States Geological Survey iron bench-mark post, 10 feet back from the gage; elevation, 9.88 feet above gage datum.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 440; 135, pp 195-196.
Discharge: 100, p 440; 135, p 196.
Discharge, monthly: 100, p 441.
Gage heights: 100, p 440; 135, p 196.
Rating table: 100, p 441.

*Discharge measurements of Succor Creek near Homedale, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square-feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| February 1 | W. C. Davies | 24 | 17 | 1.19 | 2.49 | 20 |
| February 24 | J. B. Bond | 34 | 36 | 3.00 | 3.20 | 108 |
| April 1 | La Rue and Bond | 32 | 24 | 2.17 | 2.90 | 52 |
| April 28 | E. C. La Rue | 27 | 17 | 1.24 | 2.55 | 21 |
| June 3 | do | 4 | 1.2 | 1.10 | 2.25 | 1.4 |

*Daily gage height, in feet, of Succor Creek near Homedale, Idaho, for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | Dec. |
|---|---|---|---|---|---|---|---|
| 1 | 3.65 | 2.5 | 2.7 | 3.1 | 2.3 | 2.45 | 1.9 |
| 2 | 3.55 | 2.3 | 2.7 | 3.3 | 2.2 | 2.35 | 1.9 |
| 3 | 3.5 | 2.3 | 2.75 | 3.4 | 2.25 | 2.2 | 1.9 |
| 4 | 3.5 | 2.4 | 2.7 | 3.2 | 2.35 | 2.4 | 1.95 |
| 5 | 3.45 | 2.45 | 2.7 | 3.1 | 2.35 | 2.9 | 1.95 |
| 6 | 3.45 | 2.3 | 2.7 | 3.0 | 2.35 | 2.6 | 1.95 |
| 7 | 3.45 | 2.4 | 2.65 | 2.95 | 2.25 | 2.7 | 1.95 |
| 8 | 3.45 | 2.35 | 2.6 | 2.9 | 2.25 | 3.75 | 1.95 |
| 9 | 3.45 | 2.25 | 2.6 | 2.85 | 2.2 | 2.8 | 1.95 |
| 10 | 3.45 | 2.4 | 2.6 | 2.95 | 2.2 | 2.7 | 1.95 |
| 11 | 3.45 | 2.2 | 2.65 | 2.95 | 2.1 | 2.7 | 1.95 |
| 12 | 3.45 | 2.4 | 2.65 | 2.75 | 2.25 | 6.85 | 1.95 |
| 13 | 3.45 | 2.4 | 2.6 | 2.7 | 2.15 | 2.5 | 1.95 |
| 14 | 3.45 | 2.4 | 2.65 | 2.65 | 2.1 | 2.5 | 1.9 |
| 15 | (a) | 2.5 | 2.65 | 2.7 | 2.1 | 2.3 | 1.9 |
| 16 | | 2.45 | 2.65 | 2.45 | 2.1 | 2.3 | 1.9 |
| 17 | | 2.5 | 2.65 | 2.45 | 1.9 | 2.2 | 1.9 |
| 18 | | 2.2 | 2.65 | 2.4 | 1.95 | 2.2 | 1.95 |
| 19 | | 2.2 | 2.65 | 2.4 | 2.0 | 2.15 | 1.95 |
| 20 | | 2.45 | 2.75 | 2.6 | 1.95 | 2.15 | 1.95 |
| 21 | | 3.45 | 2.7 | 2.65 | 1.9 | 2.1 | 1.95 |
| 22 | | 3.0 | 2.7 | 2.7 | 1.9 | 2.0 | 1.95 |
| 23 | | 3.2 | 2.65 | 2.6 | 1.9 | 2.0 | 1.95 |
| 24 | | 3.1 | 2.55 | 2.6 | 1.95 | 2.0 | 1.95 |
| 25 | | 3.0 | 2.65 | 2.7 | 1.95 | 2.0 | 1.95 |
| 26 | | 3.0 | 2.65 | 2.6 | 7.30 | 1.95 | 1.95 |
| 27 | | 2.8 | 3.4 | 2.6 | 2.85 | 1.9 | 1.95 |
| 28 | | 2.75 | 3.0 | 2.6 | 2.6 | 1.9 | 1.95 |
| 29 | | | 3.2 | 2.4 | 2.6 | 1.9 | 1.95 |
| 30 | | | 3.6 | 2.3 | 2.5 | 1.9 | 1.95 |
| 31 | | | 3.25 | | 2.5 | | 1.95 |

(a) Gage washed out.

NOTE.—Creek dry July 1 to November 30.

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*Estimated monthly discharge of Succor Creek near Homedale, Idaho, for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January 1-14 | 203 | 154 | 161 | 4,470 |
| February | 154 | 1 | 29.2 | 1,622 |
| March | 189 | 22 | 47.0 | 2,890 |
| April | 143 | 3 | 46.3 | 2,755 |
| May | 2,500 | .2 | 86.3 | 5,306 |
| June | 2,050 | .2 | 86.7 | 5,159 |
| July | | | .0 | 0 |
| August | | | .0 | 0 |
| September | | | .0 | 0 |
| October | | | .0 | 0 |
| November | | | .0 | 0 |
| December | .3 | .2 | .28 | 17 |
| The period | | | | 22,220 |

NOTE.—These estimates are based on five discharge measurements and slope measurements and are only approximate.

## OWYHEE RIVER NEAR OWYHEE, OREG.

This station was established August 27, 1903, by John H. Lewis. It is located at the county bridge 1½ miles from Owyhee, Oreg. Owyhee ditch takes water from the river about 6 miles above.

The channel is straight for 200 feet above and 400 feet below the station. The current is sluggish at low water. The right bank is high and rocky and will not overflow. The left bank will overflow only at extreme high water. The bed of the stream is composed of sand and gravel and is liable to shift during freshets. There are two channels at low water and one at high water.

Discharge measurements are made from the bridge at ordinary stages and by wading above the bridge at extreme low water. The initial point for soundings is the center of the upstream caisson of the left abutment.

A standard chain gage is attached to the upstream side of the bridge, near the center of the left span; length of the chain, 26.40 feet. During 1905 the gage was read once each day by D. T. Rigsby and Gilder Watson. The bench mark is the top of the steel caisson at its outer edge directly above the old gage; elevation, 18.60 feet above the gage datum.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; Bull=Bulletin; WS=Water-Supply Paper):

Description: Bull 131, pp 66–67; WS 100, pp 445–446; 135, pp 196–197.
Discharge: WS 100, p 446; 135, p 197.
Discharge, monthly: WS 135, p 199.
Discharge, flood: Ann 11, part 2, p 86.
Gage heights: Bull 131, p 67; WS 100, p 446; WS 135, p 197–198.
Rating table: Bull 131, p 67; WS 135, p 198.

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*Discharge measurements of Owyhee River near Owyhee, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| January 26 | Smith and Johnson | 287 | 547 | 1.30 | 3.50 | 709 |
| March 6 | Smith and Griffin | 286 | 594 | 1.45 | 3.69 | 862 |
| March 13 | P. H. Johnson | 284 | 578 | 1.75 | 3.90 | 1,010 |
| March 25 | Johnson and Smith | 287 | 628 | 1.64 | 3.88 | 1,033 |
| April 14 | Smith and Griffin | 289 | 629 | 1.54 | 3.90 | 966 |
| May 12 | Griffin and Hall | 284 | 567 | 1.54 | 3.70 | 874 |
| June 6 | E. N. Smith | 286 | 566 | 1.26 | 3.55 | 710 |
| June 20 | do | 138 | 310 | 1.17 | 3.01 | 362 |
| July 3 | do | 128 | 235 | .44 | 2.38 | 104 |
| July 17[a] | Yates and Smith | 27 | 20 | .80 | 1.93 | 16 |
| August 15[a] | E. N. Smith | 27 | 17.2 | .43 | 1.89 | 7.4 |
| September 12[a] | W. C. Sawyer | 33 | 11.8 | .79 | 1.90 | 8.8 |
| October 13[a] | Sawyer and Hall | 44 | 21 | 1.17 | 2.03 | 25 |
| November 9 | R. S. Hall | 130 | 250 | .53 | 2.52 | 131 |
| December 28 | do | 130 | 244 | .87 | 3.05 | 212 |

[a] Wading ¼ mile above bridge.

*Daily gage height, in feet, of Owyhee River near Owyhee, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.2 | 3.1 | 3.75 | 4.0 | 4.3 | ..... | 2.45 | 1.8 | 1.85 | 1.9 | 2.3 | 2.78 |
| 2 | 3.0 | 3.15 | 3.8 | 4.1 | 4.25 | ..... | 2.4 | 1.8 | 1.85 | 2.0 | 2.3 | 2.78 |
| 3 | 2.9 | 3.1 | 3.7 | 4.0 | 4.2 | ..... | 2.38 | 1.8 | 1.88 | 2.0 | 2.31 | 2.7 |
| 4 | 2.8 | 3.15 | 3.65 | 4.9 | 4.05 | ..... | 2.35 | 1.8 | 1.85 | 1.9 | 2.31 | 2.68 |
| 5 | 2.75 | 3.1 | 3.6 | 3.8 | 4.05 | ..... | 2.25 | 1.8 | 1.85 | 2.0 | 2.31 | 2.68 |
| 6 | 2.8 | 3.1 | 3.6 | 4.1 | 4.1 | ..... | 2.25 | 1.8 | 1.85 | 2.0 | [c]2.5 | 2.58 |
| 7 | 3.0 | 3.05 | 3.8 | [a]4.15 | 4.05 | ..... | 2.0 | 1.8 | 1.85 | 2.0 | 2.5 | 2.68 |
| 8 | 2.9 | 3.1 | 3.9 | 4.0 | 4.0 | ..... | 2.05 | 1.8 | 1.85 | 1.95 | 2.5 | 2.68 |
| 9 | 2.95 | 3.05 | 3.95 | 3.9 | 4.05 | ..... | 2.05 | 1.8 | 1.85 | 1.95 | 2.5 | 2.68 |
| 10 | 2.9 | 2.6 | 4.0 | 3.9 | 3.9 | ..... | 2.0 | 1.8 | 2.0 | 2.0 | 2.5 | 2.68 |
| 11 | 3.0 | 2.6 | 3.95 | 3.85 | 3.8 | ..... | 1.95 | 1.8 | 1.9 | 2.05 | 2.5 | 2.68 |
| 12 | 2.9 | 3.05 | 3.9 | 3.9 | 3.7 | ..... | 1.95 | 1.8 | 1.9 | 2.05 | 2.5 | 2.68 |
| 13 | 3.0 | 3.2 | 3.95 | 4.0 | 3.7 | ..... | 1.95 | 1.8 | 1.9 | 2.03 | 2.52 | 2.68 |
| 14 | 2.9 | 3.35 | 4.0 | 3.9 | 3.8 | 3.35 | 1.95 | 1.8 | 1.9 | 2.03 | 2.52 | 2.75 |
| 15 | 3.1 | 3.2 | 4.1 | 3.8 | 3.85 | 3.25 | 1.9 | 1.8 | 1.9 | 2.03 | 2.6 | 2.78 |
| 16 | 3.2 | 3.0 | 4.0 | 3.8 | 3.9 | 3.2 | 1.9 | 1.8 | 1.9 | 2.05 | 2.6 | 2.98 |
| 17 | 4.9 | 2.9 | 4.1 | 3.8 | 3.9 | 3.15 | [b]2.15 | 1.8 | 2.0 | 2.05 | 2.61 | 2.98 |
| 18 | 4.7 | 3.2 | [a]4.0 | 3.78 | 3.85 | 3.1 | 1.9 | 1.82 | 1.9 | 2.05 | 2.6 | 2.98 |
| 19 | 4.6 | 3.15 | 3.2 | 3.7 | 3.8 | 3.05 | 1.9 | 1.82 | 1.9 | 2.05 | 2.6 | 2.88 |
| 20 | 4.0 | 3.0 | 3.8 | 3.7 | 3.85 | 3.0 | 1.85 | 1.83 | 1.9 | 2.05 | 2.6 | 2.95 |
| 21 | 3.5 | 3.2 | 3.6 | 3.8 | ..... | 2.96 | 1.85 | 1.85 | 1.9 | 2.05 | 2.6 | 2.65 |
| 22 | 3.3 | 3.6 | 3.5 | 3.95 | ..... | 2.9 | 1.85 | 1.9 | 1.9 | 2.1 | 2.6 | 2.68 |
| 23 | 3.6 | 3.65 | 3.6 | 4.3 | ..... | 2.85 | 1.85 | 1.9 | 1.95 | 2.1 | 2.6 | 2.68 |
| 24 | 5.0 | 4.9 | [b]4.1 | 4.7 | ..... | 2.79 | 1.85 | 1.9 | 2.0 | 2.1 | 2.6 | 2.78 |
| 25 | 4.2 | 4.5 | 3.9 | 4.0 | ..... | 2.75 | 1.85 | 1.9 | 1.95 | 2.12 | 2.62 | 2.88 |
| 26 | 3.6 | 3.9 | 3.7 | [b]4.5 | ..... | 2.75 | 1.84 | 1.9 | 1.9 | 2.10 | 2.62 | 2.98 |
| 27 | 3.5 | 4.0 | 3.6 | 4.3 | ..... | 2.6 | 1.83 | 1.85 | 1.95 | 2.15 | 2.62 | 2.98 |
| 28 | 3.45 | 3.8 | 3.55 | 4.3 | ..... | 2.55 | 1.82 | 1.85 | 1.9 | 2.15 | 2.62 | 3.05 |
| 29 | 3.5 | ..... | 3.9 | 4.35 | ..... | 2.55 | 1.82 | 1.85 | 1.9 | 2.15 | 2.62 | 3.05 |
| 30 | 3.4 | ..... | 4.15 | 4.4 | ..... | 2.55 | [b]2.45 | 1.85 | 1.95 | [c]2.3 | 3.0 | 3.05 |
| 31 | 3.3 | ..... | 4.1 | ..... | ..... | ..... | 1.87 | 1.85 | ..... | 2.3 | ..... | 3.05 |

[a] Water turned into Owyhee ditch.
[b] Water turned from Owyhee ditch into river.
[c] Part of water turned from Owyhee ditch into river.

NOTE.—No ice record.

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*Station rating table for Owyhee River near Owyhee, Oreg., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.80 | 4 | 2.70 | 208 | 3.50 | 673 | 4.30 | 1,410 |
| 1.90 | 10 | 2.80 | 254 | 3.60 | 748 | 4.40 | 1,525 |
| 2.00 | 20 | 2.90 | 304 | 3.70 | 826 | 4.50 | 1,650 |
| 2.10 | 38 | 3.00 | 358 | 3.80 | 910 | 4.60 | 1,780 |
| 2.20 | 58 | 3.10 | 414 | 3.90 | 1,000 | 4.70 | 1,920 |
| 2.30 | 80 | 3.20 | 473 | 4.00 | 1,095 | 4.80 | 2,070 |
| 2.40 | 104 | 3.30 | 535 | 4.10 | 1,195 | 4.90 | 2,220 |
| 2.50 | 132 | 3.40 | 602 | 4.20 | 1,300 | 5.00 | 2,380 |
| 2.60 | 168 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on 15 discharge measurements made during 1905 and one during 1904. It is well defined throughout.

*Estimated monthly discharge of Owyhee River near Owyhee, Oreg., for 1905.*

[Drainage area, 9,875 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January [a] | 2,380 | 231 | 707 | 43,470 | 0.072 | 0.083 |
| February [a] | 2,200 | 168 | 600 | 33,320 | .061 | .064 |
| March | 1,248 | 473 | 941 | 57,860 | .095 | .110 |
| April | 2,220 | 826 | 1,173 | 69,800 | .119 | .133 |
| May 1-20 | 1,410 | 826 | 1,059 | 42,010 | .107 | .080 |
| June 14-30 | 568 | 150 | 317 | 10,690 | .032 | .020 |
| July | 118 | 5 | 31.9 | 1,962 | .0032 | .0037 |
| August | 10 | 4 | 5.7 | 349 | .00058 | .00067 |
| September | 20 | 7 | 10.8 | 643 | .0011 | .0012 |
| October | 80 | 10 | 31.4 | 1,931 | .0032 | .0037 |
| November | 358 | 80 | 151 | 8,985 | .015 | .017 |
| December [a] | 386 | 161 | 263 | 16,170 | .027 | .031 |
| The period | | | | 287,200 | | |

[a] Estimates may be somewhat large on account of possible ice condition.

NOTE.—To obtain the total discharge of Owyhee River the monthly estimates of Owyhee ditch should be added. See p. 120.

## DITCHES IN OWYHEE RIVER VALLEY, OREGON.

### OWYHEE DITCH NEAR OWYHEE, OREG.

This ditch diverts water from the left bank of Owyhee River, about 6 miles above Owyhee Bridge, which is used for a river gaging station.

The measurements were made just above Wilson's ranch, about 2 miles below the head of the ditch.

There are five wasteways on the ditch—the Fletcher, half a mile below the station; Cow Hollow, Lockett Gulch, Emerson, and one near the end of the ditch. The first two are above the river gaging station.

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*Discharge measurements of Owyhee ditch near Owyhee, Oreg., in 1904 and 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| 1904. | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| June 18 | Sawyer and Torkelson | | | | (a) | 154 |
| July 1 | M. W. Torkelson | | | | | 207 |
| July 13 | do | | | | | 178 |
| August 10 | Torkelson and Smith | | | | | 142 |
| September 2 | E. N. Smith | | | | | 156 |
| September 12 | do | | | | | 111 |
| September 19 | do | | | | | 117 |
| October 12 | do | | | | | 41.9 |
| 1905. | | | | | | |
| March 24 | E. N. Smith | | 9.4 | 0.64 | 0.78 | 6.0 |
| April 14 | do | | 61.5 | 2.42 | 2.95 | 149 |
| May 12 | do | 27.3 | 67.3 | 2.68 | 3.12 | 180 |
| June 5 | do | 27.0 | 66.9 | 2.75 | 3.17 | 184 |
| July 17 | do | 27.5 | 65.5 | 2.39 | 3.00 | 157 |
| July 31 | do | 26.5 | 55.2 | 2.23 | 2.60 | 123 |
| July 31 | W. C. Sawyer | 26.5 | 55.2 | 2.19 | 2.60 | 121 |
| August 15 | E. N. Smith | 27.0 | 54.8 | 2.06 | 2.53 | 113 |
| September 12 | W. C. Sawyer | 26.5 | 53.6 | 1.99 | 2.65 | 107 |
| October 2 | Hawthorne and Griffin | 26.5 | 60.4 | 2.12 | 2.88 | 128 |
| October 13 | Sawyer and Hall | 26.5 | 59.4 | 2.26 | 2.85 | 134 |

a No gage established during 1904.

*Daily gage height, in feet, of Owyhee ditch near Owyhee, Oreg., for 1905.*

| Day. | May. | June. | July. | Aug. | Sept. | Day. | May. | June | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | 2.5 | 17 | 3.5 | | 3.0 | 2.6 | |
| 2 | | 3.4 | | 2.6 | | 18 | | 3.0 | 3.3 | 2.6 | 2.8 |
| 3 | | | 3.4 | 2.5 | | 19 | 3.4 | | | 2.6 | |
| 4 | | | | 2.5 | 2.6 | 20 | | | 3.0 | | 2.7 |
| 5 | | 3.3 | | 2.5 | | 21 | | 2.8 | 2.9 | | |
| 6 | | | 3.4 | 2.5 | 2.65 | 22 | 3.5 | | 2.8 | 2.6 | |
| 7 | | 3.4 | 3.4 | 2.6 | | 23 | | 2.8 | | | 2.7 |
| 8 | | | 3.4 | 2.5 | 2.70 | 24 | 3.5 | | | 2.6 | |
| 9 | | 3.5 | 3.4 | 2.5 | | 25 | | 3.4 | | | 2.7 |
| 10 | | | | 2.5 | | 26 | 3.5 | | 2.8 | 2.6 | |
| 11 | 3.1 | 3.5 | | 2.6 | | 27 | | 3.6 | 2.7 | | 2.7 |
| 12 | 3.2 | | 3.3 | 2.3 | | 28 | | | 2.7 | | |
| 13 | 3.3 | | | 2.5 | | 29 | 3.5 | 3.5 | 2.65 | 2.55 | |
| 14 | | 3.1 | | 2.6 | | 30 | | | 2.5 | | |
| 15 | 3.5 | | | 2.5 | | 31 | 3.4 | | 2.6 | 2.5 | |
| 16 | | 3.0 | | 2.6 | | | | | | | |

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*Station rating table for Owyhee ditch near Owyhee, Oreg., from March 24 to September 6, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.70 | 4.5 | 1.50 | 38 | 2.30 | 94 | 3.00 | 154 |
| .80 | 7 | 1.60 | 44 | 2.40 | 102 | 3.10 | 163 |
| .90 | 10 | 1.70 | 50 | 2.50 | 110 | 3.20 | 172 |
| 1.00 | 14 | 1.80 | 57 | 2.60 | 118 | 3.30 | 181 |
| 1.10 | 18 | 1.90 | 64 | 2.70 | 127 | 3.40 | 190 |
| 1.20 | 23 | 2.00 | 71 | 2.80 | 136 | 3.50 | 200 |
| 1.30 | 28 | 2.10 | 78 | 2.90 | 145 | 3.60 | 210 |
| 1.40 | 33 | 2.20 | 86 | | | | |

The above table is applicable only for open-channel conditions. It is based on seven discharge measurements made during 1905. It is well defined between gage heights 2.5 feet and 3 feet. The table has been extended beyond these limits. After September 6 the table does not apply on account of back water from a diversion wing.

*Estimated monthly discharge of Owyhee ditch near Owyhee, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| May 11–31 | 200 | 163 | 194 | 8,080 |
| June | 210 | 136 | 177 | 10,530 |
| July | 190 | 110 | 162 | 9,961 |
| August | 118 | 94 | 114 | 7,010 |
| September | 127 | 107 | 114 | 6,785 |

*Discharge measurements of wasteways of Owyhee ditch in 1905.*

FLETCHER WASTEWAY NEAR OWYHEE, OREG.

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| | | *Second-feet.* |
| May 12 | E. N. Smith | 2.0 |
| October 13 | W. C. Sawyer | 6.1 |

COW HOLLOW WASTEWAY NEAR OWYHEE, OREG.

| | | |
|---|---|---|
| May 12 | E. N. Smith | 1.5 |
| June 6 | do | 2.1 |
| October 2 | Hawthorne and Griffin | 5.1 |

LOCKETT'S GULCH WASTEWAY NEAR ARCADIA, OREG.

| | | |
|---|---|---|
| May 11 | E. N. Smith | 1.4 |
| June 6 | do | 2.3 |
| October 3 | Hawthorne and Griffin | 14.6 |
| October 13 | Sawyer and Hall | 33.4 |

EMERSON WASTEWAY NEAR ARCADIA, OREG.

| | | |
|---|---|---|
| May 11 | E. N. Smith | 6.3 |
| June 20 | do | 43.7 |
| July 3 | do | 20.5 |
| October 3 | Hawthorne and Griffin | 40.7 |
| October 14 | Sawyer and Hall | 54.1 |
| November 10 | R. S. Hall | 16.6 |

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*Discharge measurements of wasteways of Owyhee ditch in 1905*—Continued.

WASTEWAY NEAR ONTARIO, OREG.

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| | | *Second-feet.* |
| October 14..... | R. S. Hall..... | 1.8 |

WILSON DITCH NEAR ONTARIO, OREG.

This ditch diverts water from the left bank of Snake River above Nyssa during the spring. All the water during the latter part of the last season was waste and seepage from the Owyhee ditch.

In 1904 measurements were made at Nyssa. The first measurement in 1905 was made at Nyssa, the last three 1 mile above Ontario, and the others about 2 miles above Ontario at Joseph Morton's ranch.

*Discharge measurements of Wilson ditch near Ontario, Oreg., in 1904 and 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| 1904. | | *Second-feet.* |
| July 13..... | M. W. Torkelson..... | 20.2 |
| August 10..... | Torkelson and Smith..... | 3.3 |
| September 1.... | E. N. Smith..... | 4.0 |
| 1905. | | |
| May 11..... | E. N. Smith..... | 9.2 |
| May 19..... | .....do..... | 9.0 |
| June 7..... | .....do..... | 7.3 |
| July 3..... | .....do..... | 8.5 |
| August 1..... | .....do..... | 0.9 |
| August 16..... | .....do..... | 1.3 |
| September 13... | W. C. Sawyer..... | 2.3 |
| October 14..... | Sawyer and Hall..... | 5.2 |

BOISE RIVER NEAR HIGHLAND, IDAHO.

This station was established on July 27, 1905, by E. C. La Rue, to replace the Boise station. A temporary station was maintained at Highland from March 23 to July 27, 1905. The permanent station is located 2 miles below the mouth of Moores Creek, 3 miles southwest of Highland post-office, about 8 miles above the old Boise station, and 15 miles east of Boise, the nearest railway point.

The channel is straight for 500 feet above the cable and 200 feet below. The water is rather swift during all stages. The right bank is very firm, rather steep, and not liable to overflow. The left bank is composed of broken lava rock and is rather steep, leading to a vertical lava cliff 30 feet in height. The bed of the stream is very firm, as it is composed of broken lava rock and granite bowlders.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is the inner face of the right cable support.

The gage is an inclined staff in two sections on the right bank, 200 feet downstream from the cable support. During 1905 the gage was read once each day by Nettie Smythe. The bench mark is a United States Geological Survey aluminum tablet set in a large bowlder on the right bank, 400 feet below the cable support; elevation, 25.44 feet above the datum of the gage.



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*Discharge measurements of Boise River near Highland, Idaho, in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| March 30 | E. C. La Rue | 183 | 726 | 2.50 | 4.30 | 1,818 |
| April 27 | do | 208 | 1,110 | 4.12 | 6.61 | 4,569 |
| May 25 | do | 207 | 852 | 3.79 | 6.20 | 3,232 |
| May 26 | do | 208 | 853 | 4.01 | 6.35 | 3,424 |
| July 19 | do | 185 | 408 | 2.40 | 3.70 | 981 |
| July 28 | do | 165 | 261 | 3.24 | [a] 3.55 | 845 |
| August 19 | do | 140 | 192 | 3.28 | [b] 3.15 | 630 |
| October 2 | do | 145 | 216 | 2.85 | 3.18 | 615 |
| October 19 | Grover and La Rue | 140 | 196 | 3.52 | 3.31 | 689 |

[a] Gage height at temporary station=3.30 on July 28.
[b] Gage height at temporary station=2.95 on August 19.

NOTE.—The first five measurements were made at the temporary station and the next four made at the permanent station.

*Daily gage height, in feet, of Boise River near Highland, Idaho, for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 4.1 | 5.85 | 8.0 | 5.2 | 3.5 | 3.0 | 3.2 | 3.35 | 3.25 |
| 2 | | 4.2 | 5.95 | 8.1 | 5.2 | 3.4 | 3.0 | 3.2 | 3.3 | 3.25 |
| 3 | | 4.25 | 6.05 | 7.9 | 5.1 | 3.4 | 3.0 | 3.15 | 3.3 | 3.25 |
| 4 | | 4.35 | 6.0 | 7.6 | 5.0 | 3.4 | 3.0 | 3.15 | 3.25 | 3.2 |
| 5 | | 4.5 | 5.85 | 7.5 | 4.9 | 3.4 | 3.0 | 3.15 | 3.25 | 3.0 |
| 6 | | 4.85 | 5.75 | 7.35 | 4.8 | 3.4 | 3.0 | 3.1 | 3.2 | 3.0 |
| 7 | | 5.3 | 5.75 | 7.3 | 4.7 | 3.3 | 3.0 | 3.1 | 3.2 | 2.9 |
| 8 | | 5.4 | 5.8 | 7.6 | 4.6 | 3.25 | 3.0 | 3.2 | 3.25 | 2.8 |
| 9 | | 5.5 | 6.1 | 7.6 | 4.5 | 3.2 | 3.0 | 3.2 | 3.3 | 2.8 |
| 10 | | 5.3 | 6.0 | 7.4 | 4.4 | 3.2 | 3.0 | 3.25 | 3.25 | 2.7 |
| 11 | | 5.1 | 5.75 | 7.4 | 4.35 | 3.2 | 3.0 | 3.25 | 3.25 | 2.7 |
| 12 | | 5.0 | 5.7 | 7.35 | 4.25 | 3.2 | 3.0 | 3.25 | 3.25 | 2.8 |
| 13 | | 5.1 | 5.55 | 7.45 | 4.15 | 3.2 | 3.0 | 3.25 | 3.25 | 2.9 |
| 14 | | 5.05 | 5.45 | 7.35 | 4.05 | 3.15 | 3.0 | 3.3 | 3.25 | 3.1 |
| 15 | | 5.05 | 5.5 | 7.05 | 4.0 | 3.15 | 3.0 | 3.3 | 3.25 | 3.25 |
| 16 | | 5.2 | 5.55 | 6.75 | 3.95 | 3.15 | 3.0 | 3.35 | 3.25 | 3.7 |
| 17 | | 5.35 | 6.1 | 6.6 | 3.85 | 3.15 | 3.0 | 3.4 | 3.25 | 3.7 |
| 18 | 4.45 | 5.25 | 7.0 | 6.5 | 3.8 | 3.15 | 3.05 | 3.35 | 3.25 | 3.7 |
| 19 | 4.35 | 5.5 | 7.1 | 6.1 | 3.75 | 3.15 | 3.05 | 3.3 | 3.25 | 3.6 |
| 20 | 4.15 | 5.8 | 7.1 | 5.95 | 3.7 | 3.1 | 3.05 | 3.25 | 3.25 | 3.5 |
| 21 | 4.1 | 5.8 | 7.1 | 6.1 | 3.65 | 3.1 | 3.05 | 3.3 | 3.25 | 3.45 |
| 22 | 4.1 | 5.75 | 6.75 | 6.0 | 3.6 | 3.05 | 3.05 | 3.35 | 3.3 | 3.0 |
| 23 | 4.1 | 5.9 | 6.7 | 5.95 | 3.55 | 3.05 | 3.05 | 3.35 | 3.3 | 2.9 |
| 24 | 4.1 | 5.9 | 6.5 | 5.9 | 3.45 | 3.05 | 3.05 | 3.4 | 3.3 | 2.9 |
| 25 | 4.1 | 6.2 | 6.3 | 5.9 | 3.4 | 3.05 | 3.1 | 3.45 | 3.3 | 3.05 |
| 26 | 4.45 | 6.5 | 6.35 | 5.8 | 3.35 | 3.05 | 3.1 | 3.4 | 3.3 | 3.15 |
| 27 | 4.6 | 6.6 | 7.2 | 5.7 | 3.3 | 3.05 | 3.15 | 3.35 | 3.3 | 3.15 |
| 28 | 4.35 | 6.3 | 7.0 | 5.6 | 3.3 | 3.05 | 3.15 | 3.35 | 3.3 | 3.4 |
| 29 | 4.35 | 6.1 | 7.6 | 5.45 | 3.25 | 3.0 | 3.2 | 3.35 | 3.25 | 3.5 |
| 30 | 4.3 | 6.0 | 7.4 | 5.3 | 3.2 | 3.0 | 3.2 | 3.35 | 3.25 | 3.4 |
| 31 | 4.1 | ..... | 7.45 | ..... | 3.15 | 3.0 | ..... | 3.35 | ..... | 3.25 |

NOTE.—No ice record.

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*Daily discharge, in second-feet, of Boise River near Highland, Idaho, for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1,650 | 3,350 | 6,070 | 2,150 | 820 | 560 | 650 | 730 | 675 |
| 2 | ..... | 1,710 | 3,470 | 6,260 | 2,150 | 760 | 560 | 650 | 700 | 675 |
| 3 | ..... | 1,750 | 3,590 | 5,890 | 2,060 | 760 | 560 | 625 | 700 | 675 |
| 4 | ..... | 1,840 | 3,490 | 5,380 | 1,970 | 760 | 560 | 625 | 675 | 650 |
| 5 | ..... | 1,970 | 3,260 | 5,180 | 1,870 | 760 | 560 | 625 | 675 | 560 |
| 6 | ..... | 2,320 | 3,100 | 4,940 | 1,790 | 760 | 560 | 600 | 650 | 560 |
| 7 | ..... | 2,810 | 3,080 | 4,860 | 1,710 | 700 | 560 | 600 | 650 | 520 |
| 8 | ..... | 2,920 | 3,120 | 5,360 | 1,630 | 675 | 560 | 650 | 675 | 480 |
| 9 | ..... | 3,050 | 3,510 | 5,360 | 1,550 | 650 | 560 | 650 | 700 | 480 |
| 10 | ..... | 2,810 | 3,350 | 5,010 | 1,470 | 650 | 560 | 675 | 675 | 450 |
| 11 | ..... | 2,570 | 2,980 | 5,010 | 1,430 | 650 | 560 | 675 | 675 | 450 |
| 12 | ..... | 2,470 | 2,900 | 4,920 | 1,350 | 650 | 560 | 675 | 675 | 480 |
| 13 | ..... | 2,570 | 2,710 | 5,090 | 1,270 | 650 | 560 | 675 | 675 | 520 |
| 14 | ..... | 2,490 | 2,580 | 4,930 | 1,210 | 625 | 560 | 700 | 675 | 600 |
| 15 | ..... | 2,490 | 2,610 | 4,460 | 1,170 | 625 | 560 | 700 | 675 | 675 |
| 16 | ..... | 2,660 | 2,650 | 4,000 | 1,140 | 625 | 560 | 730 | 675 | 940 |
| 17 | ..... | 2,820 | 3,300 | 3,990 | 1,070 | 625 | 560 | 760 | 675 | 940 |
| 18 | 1,930 | 2,710 | 4,600 | 3,650 | 1,030 | 625 | 580 | 730 | 675 | 940 |
| 19 | 1,850 | 2,980 | 4,740 | 3,110 | 1,010 | 625 | 580 | 700 | 675 | 880 |
| 20 | 1,660 | 3,380 | 4,710 | 2,930 | 990 | 600 | 580 | 675 | 675 | 820 |
| 21 | 1,630 | 3,380 | 4,670 | 3,120 | 970 | 600 | 580 | 700 | 675 | 790 |
| 22 | 1,630 | 3,320 | 4,100 | 2,990 | 950 | 580 | 580 | 730 | 700 | 560 |
| 23 | 1,630 | 3,540 | 3,990 | 2,930 | 930 | 580 | 580 | 730 | 700 | 520 |
| 24 | 1,640 | 3,540 | 3,670 | 2,880 | 880 | 580 | 580 | 760 | 700 | 520 |
| 25 | 1,640 | 3,950 | 3,360 | 2,880 | 860 | 580 | 600 | 790 | 700 | 580 |
| 26 | 1,940 | 4,410 | 3,430 | 2,770 | 840 | 580 | 600 | 760 | 700 | 625 |
| 27 | 2,090 | 4,570 | 4,700 | 2,670 | 820 | 580 | 625 | 730 | 700 | 625 |
| 28 | 1,860 | 4,070 | 4,380 | 2,560 | 820 | 580 | 625 | 730 | 700 | 760 |
| 29 | 1,860 | 3,760 | 5,360 | 2,390 | 810 | 560 | 650 | 730 | 675 | 820 |
| 30 | 1,820 | 3,590 | 5,030 | 2,240 | 780 | 560 | 650 | 730 | 675 | 760 |
| 31 | 1,650 | ..... | 5,120 | ..... | 750 | 560 | ..... | 730 | ..... | 675 |

NOTE.—March 18 to July 31 discharge obtained indirectly; August 1 to December 31 discharge obtained from rating table based on four measurements made at permanent station.

*Estimated monthly discharge of Boise River near Highland, Idaho, for 1905.*

[Drainage area, 2,614 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| March 18-31 | 2,090 | 1,630 | 1,774 | 49,260 | 0.679 | 0.354 |
| April | 4,570 | 1,650 | 2,937 | 174,800 | 1.12 | 1.25 |
| May | 5,360 | 2,580 | 3,707 | 227,900 | 1.42 | 1.64 |
| June | 6,260 | 2,240 | 4,121 | 245,200 | 1.58 | 1.76 |
| July | 2,150 | 750 | 1,272 | 78,210 | .487 | .562 |
| August | 820 | 560 | 643 | 39,540 | .246 | .284 |
| September | 650 | 560 | 578 | 34,390 | .221 | .247 |
| October | 790 | 600 | 693 | 42,610 | .265 | .306 |
| November | 730 | 650 | 684 | 40,700 | .262 | .292 |
| December | 940 | 450 | 652 | 40,090 | .249 | .287 |
| The period | ..... | ..... | ..... | 972,700 | ..... | ..... |

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## MALHEUR RIVER NEAR WESTFALL, OREG.

This station was established December 15, 1903, by John H. Lewis, and was discontinued October 31, 1905. It is located 3 miles below the Harper ranch, near Westfall, 22 miles above Vale, Oreg.

The channel is straight for about 1,000 feet above and 200 feet below the station and the current is swift. The right bank is low, covered with sage brush, and overflows during high water. The left bank is high, rocky, and not liable to overflow. The bed of the stream is composed of gravel and sand and is free from vegetation and shifting. There is but one channel at low water and the main channel and two sloughs at high stages.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is the zero of the tagged wire.

The original gage was a staff attached vertically to a frame bent of a bridge which formerly occupied this site, on the left bank. An inclined gage was established on the right bank, 50 feet above the cable, July 27, 1904, the datum being changed. During 1905 the gage was read at varying intervals by Clarence Vines. The bench mark is a nail in the top of the post to which the stay wire is fastened; elevation, 15.92 feet above the datum of the inclined gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 427–428; 135, p 203.
Discharge: 100, p 428; 135, p 204.
Discharge, monthly: 135, p 205.
Gage heights: 100, p 428; 135, p 204.
Rating table: 135, p 205.

*Discharge measurements of Malheur River near Westfall, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet* | *Feet per second.* | *Feet* | *Second-feet.* |
| February 6 | Smith and Griffin | 188 | 135 | 2.12 | 5.78 | 288 |
| March 3 | Smith and Johnson | 195 | 437 | 3.70 | 7.09 | 1,618 |
| March 4 | E. N. Smith | 197 | 459 | 3.65 | 7.20 | 1,680 |
| March 13 | do | 202 | 532 | 3.74 | 7.72 | 1,990 |
| March 14 | do | 202 | 550 | 4.10 | 7.82 | 2,250 |
| March 28 | J. M. Griffin | 193 | 303 | 3.42 | 6.70 | 1,035 |
| April 17 | do | 192 | 232 | 2.44 | 6.40 | 567 |
| May 19 | Griffin and Smith | 189 | 133 | 2.48 | 5.83 | 304 |
| June 13 | E. N. Smith | 189 | 157 | 2.38 | 5.89 | 374 |
| June 19 | do | 188 | 119 | 2.00 | 5.70 | 236 |
| July 18 | Smith and Yates | 44 | 32 | 1.38 | 5.13 | 44 |
| September 1 | E. N. Smith | 34 | 20 | 1.01 | 4.94 | 20 |

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*Daily gage height, in feet, of Malheur River near Westfall, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | 6.5 | 6.2 | 5.9 | | | | |
| 2 | | | | 6.5 | 6.2 | | 5.5 | | 4.9 | |
| 3 | | | 7.1 | 6.7 | 6.2 | | | | | |
| 4 | | | 7.2 | 6.9 | 6.1 | | | | | |
| 5 | | | 7.0 | 7.0 | 6.1 | 5.8 | | 4.9 | | |
| 6 | | | 7.0 | 6.7 | 6.1 | | | | | |
| 7 | | | 7.1 | 6.6 | 6.0 | | 5.4 | | | 5.3 |
| 8 | | | 7.0 | 6.6 | 6.0 | | | | | |
| 9 | | | 6.8 | 6.7 | 6.0 | 5.8 | | | 5.0 | |
| 10 | | | 6.9 | 6.7 | 6.0 | | | | | |
| 11 | | | 7.1 | 6.7 | 6.0 | | 5.3 | | | |
| 12 | | | 7.4 | 6.7 | 6.0 | | | 4.6 | | |
| 13 | | | 7.7 | 6.6 | 6.0 | 5.9 | | | | |
| 14 | | | 7.8 | 6.5 | 5.9 | | 5.2 | | | 5.4 |
| 15 | | | 7.4 | 6.5 | 5.8 | | | | | |
| 16 | | | 7.2 | 6.5 | 5.8 | 5.8 | | | 5.1 | |
| 17 | | | 7.1 | 6.4 | 5.7 | | | | | |
| 18 | | | 6.9 | 6.4 | 5.7 | | 5.1 | | | |
| 19 | | | 6.9 | 6.4 | 5.6 | 5.6 | | | | |
| 20 | | | 7.0 | 6.4 | | | | | | |
| 21 | | | 7.4 | 6.4 | | | 5.0 | | | 5.5 |
| 22 | | | 7.2 | 6.4 | 5.6 | | | 4.95 | | |
| 23 | | | 6.9 | 6.3 | | 5.6 | | | 5.2 | |
| 24 | 9.0 | | 6.9 | 6.3 | | | | | | |
| 25 | 7.3 | | 6.9 | 6.3 | | | | | | |
| 26 | 7.0 | | 6.7 | 6.3 | 5.7 | 5.5 | | 4.9 | | |
| 27 | 6.5 | | 6.7 | 6.3 | | | | | | |
| 28 | | | 6.7 | 6.3 | | | 4.9 | | | 5.6 |
| 29 | | | 6.6 | 6.3 | | | | | | |
| 30 | | | 6.6 | 6.2 | 6.7 | 5.5 | | | 5.2 | |
| 31 | | | 6.5 | | | | 4.9 | | | |

NOTE.—Owing to distance of observer from gage, daily readings were made only during high water.

*Station rating table for Malheur River near Westfall, Oreg., from January 1 to October 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 4.60 | 15 | 5.80 | 297 | 6.90 | 1,242 | 8.00 | 2,580 |
| 4.70 | 16 | 5.90 | 360 | 7.00 | 1,350 | 8.10 | 2,725 |
| 4.80 | 17 | 6.00 | 430 | 7.10 | 1,459 | 8.20 | 2,874 |
| 4.90 | 19 | 6.10 | 503 | 7.20 | 1,569 | 8.30 | 3,028 |
| 5.00 | 25 | 6.20 | 580 | 7.30 | 1,681 | 8.40 | 3,187 |
| 5.10 | 40 | 6.30 | 661 | 7.40 | 1,796 | 8.50 | 3,350 |
| 5.20 | 59 | 6.40 | 747 | 7.50 | 1,915 | 8.60 | 3,515 |
| 5.30 | 82 | 6.50 | 840 | 7.60 | 2,038 | 8.70 | 3,682 |
| 5.40 | 110 | 6.60 | 936 | 7.70 | 2,165 | 8.80 | 3,851 |
| 5.50 | 146 | 6.70 | 1,035 | 7.80 | 2,298 | 8.90 | 4,024 |
| 5.60 | 189 | 6.80 | 1,137 | 7.90 | 2,437 | 9.00 | 4,200 |
| 5.70 | 239 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on 12 discharge measurements made during 1905. It is fairly well defined throughout.

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*Estimated monthly discharge of Malheur River near Westfall, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| March 3–31 | 2,298 | 840 | 1,386 | 79,730 |
| April | 1,350 | 580 | 850 | 50,580 |
| May | 1,035 | 189 | 413 | 25,390 |
| June | 360 | 146 | 253 | 15,060 |
| July | 146 | 19 | 62.5 | 3,843 |
| August | 21 | 15 | 18.5 | 1,138 |
| September | 59 | 19 | 40.4 | 2,404 |
| October | 189 | 82 | 132 | 8,116 |
| The period | | | | 186,300 |

NOTE.—Gage heights were interpolated for days when there was no reading.

## MALHEUR RIVER AT VALE, OREG.

This station was established May 20, 1903, by N. S. Dils. It is located at the steel highway bridge one-eighth mile southeast of Vale, Oreg. A station has been maintained here at intervals since 1890.

The channel is straight for about 200 feet above and 300 feet below the station, and the current is swift. The right bank is high, rocky, free from vegetation, and does not overflow. The left bank is low, and is composed of firm earth, covered with small sagebrush, and is liable to overflow at high water, when the water flows in two sloughs on the left bank, which can be measured by wading. The bed of the stream is composed of gravel and sand and is free from vegetation and liable to shift. There is but one channel at all stages, with the exception of the above-mentioned sloughs. The lower portion of the drainage area is covered with sagebrush, and the snow is melted very rapidly by warm winds, causing sudden floods of considerable height but of short duration.

Discharge measurements were originally made from the upstream side of the bridge. March 2, 1904, a cable, car, and tagged and stay wires were installed about one-fourth mile downstream, directly opposite the town of Vale. The initial point for soundings is the zero of the tagged wire on the left bank.

The original gage was replaced July 25, 1904, by a standard chain gage attached to the downstream side of the bridge, near the center of the span; length of chain, 30.41 feet. The datum is the same. During 1905 the gage was read twice each day by Isaac McCumsey and Z. G. Wilson. The bench mark is the top surface of the east steel caisson at the north end of the bridge; elevation, 21.63 feet above the datum of the gage and 2,236.56 feet above sea level.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; Bull=Bulletin; WS=Water-Supply Paper):

Description: Ann 18, iv, p 348; Bull 131, p 68; 140, p 242; WS 16, p 169; 100, pp 424–425; 135, p 206.
Discharge: Ann 11, ii, p 88; 18, iv, p 348; Bull 131, pp 68, 92; 140, p 242; WS 16, p 169; 100, p 425; 135, p 207.
Discharge, monthly: Ann 11, ii, p 106; 12, ii, pp 358, 361; 13, iii, p 98; 18, iv, pp 349–350; WS 100, p 427; 135, p 208.
Discharge, yearly: Ann 13, iii, p 99; 20, iv, p 62.
Gage heights: Bull 140, p 243; WS 11, p 83; 16, p 169; 100, p 426; 135, p 207.
Hydrograph: Ann 12, ii, p 344.
Rating tables: Ann 18, iv, p 349; WS 100, p 426; 135, p 208.

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*Discharge measurements of Malheur River at Vale, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| January 25 | Smith and Johnson | 148 | 647 | 2.95 | 7.00 | 1,900 |
| January 28 | do | 117 | 360 | 2.20 | 5.50 | 800 |
| February 4 | do | 105 | 250 | 1.22 | 4.68 | 306 |
| February 8 | E. N. Smith | 102 | 228 | .99 | 4.40 | 226 |
| February 23 | Smith and Griffin | 140 | 453 | 2.55 | 6.15 | 1,155 |
| February 24 | do | 148 | 570 | 3.74 | 7.00 | 2,130 |
| March 2 | E. N. Smith | 139 | 560 | 2.90 | 6.46 | 1,620 |
| March 9 | J. M. Griffin | 133 | 491 | 2.87 | 6.45 | 1,405 |
| March 14 | P. H. Johnson | 150 | 764 | 3.38 | 7.35 | 2,580 |
| March 18 | do | 144 | 540 | 2.87 | 6.40 | 1,550 |
| March 22 | Smith and Johnson | 141 | 570 | 3.13 | 6.80 | 1,780 |
| March 27 | do | 134 | 465 | 2.75 | 6.08 | 1,281 |
| April 11 | J. M. Griffin | 138 | 435 | 2.56 | 6.10 | 1,110 |
| April 19 | do | 130 | 350 | 2.10 | 5.60 | 740 |
| April 26 | do | 123 | 280 | 1.90 | 5.30 | 533 |
| May 17 | do | 101 | 166 | 1.07 | 4.40 | 178 |
| June 5 | E. N. Smith | 109 | 235 | 1.46 | 4.70 | 343 |
| June 12 | do | 108 | 227 | 1.76 | 5.00 | 410 |
| June 26 | do | 100 | 146 | .79 | 4.15 | 115 |
| July 4 | do | 92 | 120 | .67 | 3.90 | 80 |
| July 10 | do | 92 | 95 | .40 | 3.78 | 38.0 |
| July 21 | do | 21 | 30 | 1.15 | 3.71 | 34.7 |
| July 29 | do | 20 | 25 | 1.10 | 3.67 | 27.6 |
| August 4 | do | 20 | 22 | 1.02 | 3.62 | 22.5 |
| August 11 | do | 20 | 18.3 | 1.09 | 3.59 | 16.9 |
| August 17 | do | 19 | 17.3 | .79 | 3.58 | 13.7 |
| September 8 | G. Stubblefield | 20 | 19.7 | .95 | 3.62 | 18.7 |
| October 14 | R. S. Hall | 10 | 9.4 | 4.75 | 3.90 | 48 |
| November 4 | do | 38 | 52 | 1.72 | 4.10 | 90 |
| December 27 | do | 99 | 136 | 85 | 4.30 | 115 |

*Daily gage height, in feet, of Malheur River at Vale, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.35 | 4.85 | 6.35 | 5.9 | 5.13 | 4.45 | 4.0 | 3.62 | 3.56 | 3.8 | 4.15 | 4.28 |
| 2 | 4.75 | 4.7 | 6.5 | 6.0 | 5.1 | 4.47 | 4.0 | 3.63 | 3.57 | 3.81 | 4.06 | 4.19 |
| 3 | 4.6 | 4.7 | 6.55 | 6.3 | 5.1 | 4.38 | 4.0 | 3.6 | 3.58 | 3.84 | 4.08 | 4.29 |
| 4 | 4.8 | 4.7 | 6.45 | 6.45 | 4.97 | 4.45 | 3.9 | 3.6 | 3.6 | 3.86 | 4.1 | 4.43 |
| 5 | 4.7 | 4.6 | 6.7 | 6.25 | 4.92 | 4.7 | 3.9 | 3.57 | 3.6 | 3.86 | 4.11 | 4.41 |
| 6 | 4.6 | 4.6 | 6.6 | 5.97 | 4.88 | 4.6 | 3.9 | 3.6 | 3.6 | 3.88 | 4.16 | 4.35 |
| 7 | 4.6 | 4.55 | 6.75 | 5.9 | 4.77 | 4.7 | 3.85 | 3.59 | 3.6 | 3.88 | 4.14 | 4.37 |
| 8 | 4.6 | 4.5 | 6.75 | 6.23 | 4.7 | 5.05 | 3.85 | 3.56 | 3.62 | 3.86 | 4.16 | 4.4 |
| 9 | 4.4 | 4.45 | 6.45 | 6.3 | 4.63 | 5.05 | 3.77 | 3.54 | 3.63 | 3.86 | 4.17 | 4.05 |
| 10 | 4.2 | 4.45 | 6.4 | 6.13 | 4.6 | 5.02 | 3.73 | 3.59 | 3.63 | 3.88 | 4.16 | 4.36 |
| 11 | 4.25 | 4.4 | 6.5 | 6.12 | 4.52 | 5.1 | 3.7 | 3.56 | 3.66 | 3.86 | 4.2 | 4.31 |
| 12 | 4.25 | 4.45 | 6.8 | 6.0 | 4.5 | 4.97 | 3.65 | 3.59 | 3.68 | 3.9 | 4.16 | 3.9 |
| 13 | 4.25 | 4.25 | 7.1 | 5.85 | 4.5 | 4.85 | 3.62 | 3.58 | 3.68 | 3.9 | 4.18 | 3.79 |
| 14 | 4.35 | 4.4 | 7.3 | 5.85 | 4.5 | 4.7 | 3.6 | 3.54 | 3.69 | 3.9 | 4.11 | 3.92 |
| 15 | 4.15 | 4.5 | 7.15 | 5.78 | 4.45 | 4.63 | 3.6 | 3.54 | 3.68 | 3.9 | 4.19 | 4.24 |
| 16 | 4.30 | 4.55 | 6.7 | 5.67 | 4.4 | 4.52 | 3.68 | 3.49 | 3.69 | 3.98 | 4.2 | 4.15 |
| 17 | 4.55 | 4.5 | 6.5 | 5.55 | 4.33 | 4.5 | 3.67 | 3.54 | 3.72 | 4.01 | 4.21 | 4.2 |

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*Daily gage height, in feet, of Malheur River at Vale, Oreg., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 5.4 | 4.4 | 6.4 | 5.5 | 4.2 | 4.45 | 3.7 | 3.54 | 3.76 | 4.07 | 4.26 | 4.26 |
| 19 | 5.05 | 4.35 | 6.45 | 5.6 | 4.2 | 4.65 | 3.75 | 3.55 | 3.78 | 4.06 | 4.2 | 4.3 |
| 20 | 5.4 | 4.5 | 6.45 | 5.5 | 4.2 | 4.4 | 3.75 | 3.58 | 3.79 | 4.1 | 4.24 | 4.36 |
| 21 | 5.35 | 4.6 | 6.8 | 5.5 | 4.2 | 4.32 | 3.7 | 3.58 | 3.8 | 4.12 | 4.24 | 4.47 |
| 22 | 5.15 | 5.95 | 6.8 | 5.5 | 4.2 | 4.25 | 3.7 | 3.59 | 3.8 | 4.1 | 4.22 | 4.82 |
| 23 | 5.6 | 6.3 | 6.55 | 5.43 | 4.17 | 4.2 | 3.65 | 3.59 | 3.82 | 4.08 | 4.18 | 4.72 |
| 24 | 7.95 | 6.95 | 6.45 | 5.42 | 4.15 | 4.15 | 3.65 | 3.6 | 3.84 | 4.1 | 4.08 | 4.3 |
| 25 | 6.92 | 7.25 | 6.35 | 5.4 | 4.15 | 4.15 | 3.65 | 3.61 | 3.82 | 4.12 | 4.18 | 4.42 |
| 26 | 6.17 | 7.1 | 6.22 | 5.35 | 4.15 | 4.15 | 3.62 | 3.59 | 3.82 | 4.1 | 4.26 | 4.31 |
| 27 | 5.74 | 6.85 | 6.08 | 5.28 | 4.25 | 4.1 | 3.6 | 3.57 | 3.83 | 4.13 | 4.31 | 4.27 |
| 28 | 5.5 | 6.55 | 6.12 | 5.3 | 4.6 | 4.5 | 3.6 | 3.58 | 3.84 | 4.14 | 4.34 | 4.64 |
| 29 | 5.35 | ..... | 6.05 | 5.32 | 4.58 | 4.0 | 3.6 | 3.57 | 3.82 | 4.18 | 4.33 | 4.5 |
| 30 | 5.15 | ..... | 5.98 | 5.23 | 4.9 | 4.3 | 3.62 | 3.58 | 3.83 | 4.14 | 4.34 | 4.34 |
| 31 | 5.0 | ..... | 5.9 | ..... | 4.65 | ..... | 3.63 | 3.57 | ..... | 4.14 | ..... | 4.31 |

NOTE.—Ice conditions during part of January and December.

*Daily discharge, in second-feet, of Malheur River at Vale, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 132 | 386 | 1,524 | 1,088 | 452 | 239 | 88 | 20 | 14 | 44 | 109 | 140 |
| 2 | 258 | 318 | 1,673 | 1,168 | 436 | 247 | 98 | 22 | 15 | 46 | 90 | 118 |
| 3 | 204 | 318 | 1,725 | 1,382 | 436 | 214 | 98 | 18 | 16 | 50 | 94 | 142 |
| 4 | 277 | 318 | 1,673 | 1,524 | 372 | 239 | 78 | 18 | 18 | 54 | 98 | 182 |
| 5 | 239 | 277 | 1,778 | 1,338 | 349 | 340 | 78 | 15 | 18 | 54 | 100 | 176 |
| 6 | 204 | 277 | 1,572 | 1,065 | 331 | 298 | 78 | 18 | 18 | 57 | 111 | 159 |
| 7 | 204 | 277 | 1,778 | 1,013 | 285 | 318 | 60 | 17 | 18 | 57 | 107 | 165 |
| 8 | 204 | 258 | 1,725 | 1,276 | 277 | 490 | 60 | 14 | 20 | 54 | 111 | 173 |
| 9 | 145 | 239 | 1,426 | 1,293 | 250 | 462 | 40 | 12 | 22 | 54 | 113 | 88 |
| 10 | 98 | 239 | 1,382 | 1,151 | 239 | 446 | 34 | 17 | 22 | 57 | 111 | 162 |
| 11 | 109 | 222 | 1,475 | 1,143 | 211 | 462 | 30 | 14 | 25 | 54 | 120 | 148 |
| 12 | 109 | 239 | 1,887 | 1,050 | 204 | 396 | 24 | 17 | 28 | 60 | 111 | 60 |
| 13 | 109 | 159 | 2,237 | 940 | 204 | 340 | 20 | 16 | 28 | 60 | 116 | 43 |
| 14 | 132 | 204 | 2,486 | 940 | 204 | 277 | 18 | 12 | 29 | 60 | 100 | 64 |
| 15 | 88 | 239 | 2,298 | 890 | 188 | 250 | 18 | 12 | 28 | 60 | 118 | 120 |
| 16 | 120 | 258 | 1,778 | 814 | 173 | 211 | 28 | 7 | 29 | 74 | 120 | 109 |
| 17 | 188 | 222 | 1,622 | 733 | 153 | 204 | 26 | 12 | 34 | 80 | 122 | 120 |
| 18 | 575 | 188 | 1,524 | 700 | 120 | 188 | 30 | 12 | 38 | 92 | 135 | 140 |
| 19 | 386 | 173 | 1,572 | 766 | 120 | 258 | 37 | 13 | 41 | 90 | 120 | 145 |
| 20 | 575 | 222 | 1,524 | 700 | 120 | 173 | 37 | 16 | 43 | 98 | 130 | 162 |
| 21 | 546 | 239 | 1,832 | 700 | 120 | 151 | 30 | 16 | 44 | 102 | 130 | 195 |
| 22 | 436 | 1,013 | 1,778 | 700 | 132 | 132 | 30 | 17 | 44 | 98 | 125 | 327 |
| 23 | 706 | 1,293 | 1,524 | 624 | 125 | 120 | 24 | 17 | 47 | 94 | 116 | 285 |
| 24 | 3,098 | 2,058 | 1,475 | 618 | 120 | 109 | 24 | 18 | 50 | 98 | 94 | 145 |
| 25 | 1,800 | 2,423 | 1,428 | 605 | 120 | 109 | 24 | 19 | 47 | 102 | 116 | 179 |
| 26 | 1,168 | 2,237 | 1,355 | 575 | 120 | 109 | 20 | 17 | 47 | 98 | 135 | 148 |
| 27 | 911 | 2,000 | 1,281 | 534 | 159 | 98 | 18 | 15 | 50 | 105 | 148 | 138 |
| 28 | 800 | 1,673 | 1,225 | 546 | 277 | 204 | 18 | 16 | 50 | 107 | 156 | 254 |
| 29 | 700 | ..... | 1,250 | 558 | 269 | 88 | 18 | 15 | 47 | 116 | 153 | 204 |
| 30 | 575 | ..... | 1,192 | 506 | 410 | 159 | 20 | 16 | 48 | 107 | 156 | 156 |
| 31 | 490 | ..... | 1,088 | ..... | 298 | ..... | 22 | 15 | ..... | 107 | ..... | 148 |

NOTE.—Owing to changeable bed the daily discharge has been obtained indirectly.

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*Estimated monthly discharge of Malheur River at Vale, Oreg., for 1905.*

[Drainage area, 4,190 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 3,098 | 88 | 503 | 30,930 | 0.120 | 0.138 |
| February | 2,423 | 159 | 642 | 35,660 | .153 | .159 |
| March | 2,486 | 1,088 | 1,616 | 99,360 | .386 | .445 |
| April | 1,524 | 506 | 898 | 53,440 | .214 | .239 |
| May | 452 | 120 | 235 | 14,450 | .056 | .065 |
| June | 490 | 88 | 244 | 14,520 | .058 | .065 |
| July | 98 | 18 | 39.6 | 2,435 | .0095 | .011 |
| August | 22 | 7 | 15.6 | 959 | .0037 | .0043 |
| September | 50 | 14 | 32.6 | 1,940 | .0078 | .0087 |
| October | 116 | 44 | 77.1 | 4,741 | .018 | .021 |
| November | 156 | 90 | 119 | 7,081 | .028 | .031 |
| December | 327 | 43 | 155 | 9,531 | .037 | .043 |
| The year | 3,098 | 7 | 381 | 275,000 | .098 | 1.23 |

NOTE.—Estimates during January and December may be slightly large owing to ice conditions.

## MALHEUR RIVER AT M'LAUGHLIN'S BRIDGE, NEAR VALE, OREG.

This station was established December 10, 1904, by W. C. Sawyer. It is located at the new county bridge, known as McLaughlin's bridge, 10 miles above Vale, Oreg.

Discharge measurements are made from the iron bridge to which the gage is fastened, consisting of two spans and wooden approaches.

A standard chain gage is attached to the upstream hand rail of the bridge, near the left bank; length of the chain, 21.72 feet. In 1905 the gage was read weekly during a portion of January and February and daily during the remainder of the year by R. N. Linebarger.

A description of this station is contained in Water-Supply Paper No. 135, United States Geological Survey, page 109.

*Discharge measurements of Malheur River at McLaughlin's bridge, near Vale, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| January 28 | Smith and Johnson | 84 | 160 | 4.56 | 3.80 | 730 |
| February 27 | do | 110 | 310 | 4.87 | 4.70 | 1,510 |
| March 2 | Griffin and Johnson | 98 | 290 | 4.55 | 4.50 | 1,320 |
| March 12 | E. N. Smith | 112 | 355 | 4.93 | 5.00 | 1,750 |
| March 14 | do | 153 | 409 | 5.21 | 5.41 | 2,133 |
| April 1 | Smith and Griffin | 96 | 223 | 4.35 | 4.00 | 970 |
| April 17 | J. M. Griffin | 90 | 260 | 3.43 | 3.90 | 890 |
| April 30 | do | 112 | 127 | 3.76 | 3.60 | 478 |
| May 6 | do | 79 | 138 | 3.15 | 3.35 | 434 |
| May 16 | do | 76 | 128 | 2.30 | 3.00 | 294 |
| June 14 | E. N. Smith | 78 | 143 | 2.39 | 3.10 | 342 |
| June 28 | do | 74 | 99 | 1.10 | 2.60 | 112 |
| July 18 | Yates and Smith | 67 | 73 | .49 | 2.30 | 36 |
| July 28 | Smith and Sawyer | 67 | 82 | .41 | 2.21 | 34 |
| August 4 | E. N. Smith | 16 | 9.8 | 1.60 | 2.18 | 16 |
| August 12 [a] | do | 14 | 8.2 | 1.16 | 2.12 | 10 |
| September 2 | do | 16 | 9.3 | 1.50 | 2.12 | 14 |
| October 12 [b] | Sawyer and Hall | 38 | 23 | 2.78 | 2.38 | 64 |
| November 6 | R. S. Hall | 73 | 98 | 1.23 | 2.58 | 120 |

[a] One-half mile above bridge.

[b] About 300 feet above bridge.

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*Daily gage height, in feet, of Malheur River at McLaughlin's bridge, near Vale, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.0 | 3.2 | 4.6 | 4.0 | 3.45 | 2.93 | 2.6 | 2.2 | 2.12 | 2.4 | 2.6 | 3.0 |
| 2 | 3.0 | 3.1 | 4.56 | 4.07 | 3.5 | 2.95 | 2.5 | 2.18 | 2.12 | 2.4 | 2.6 | 2.9 |
| 3 | 3.0 | 3.1 | 4.59 | 4.45 | 3.5 | 2.9 | 2.5 | 2.2 | 2.15 | 2.4 | 2.6 | 2.9 |
| 4 | 3.0 | 3.05 | 4.66 | 4.6 | 3.45 | 3.0 | 2.48 | 2.18 | 2.15 | 2.4 | 2.6 | 2.8 |
| 5 | 3.0 | 3.0 | 4.65 | 4.27 | 3.4 | 3.1 | 2.45 | 2.15 | 2.15 | 2.4 | 2.6 | 2.75 |
| 6 | 2.97 | 3.0 | 4.62 | 4.1 | 3.3 | 3.1 | 2.43 | 2.15 | 2.15 | 2.4 | 2.6 | 2.75 |
| 7 | 3.0 | 2.9 | 4.8 | 7.1 | 3.2 | 3.25 | 2.4 | 2.15 | 2.18 | 2.4 | 2.6 | 2.65 |
| 8 | 3.0 | 2.9 | 4.7 | 4.15 | 3.1 | 3.7 | 2.4 | 2.12 | 2.18 | 2.4 | 2.6 | 2.7 |
| 9 | 3.05 | 2.9 | 4.55 | 4.27 | 3.05 | 3.3 | 2.4 | 2.15 | 2.2 | 2.4 | 2.6 | 2.7 |
| 10 | 3.05 | 2.9 | 4.65 | 4.25 | 3.05 | 3.4 | 2.33 | 2.15 | 2.22 | 2.4 | 2.6 | 2.7 |
| 11 | 3.1 | 3.25 | 4.7 | 4.25 | 3.0 | 3.3 | 2.25 | 2.13 | 2.22 | 2.4 | 2.6 | 2.75 |
| 12 | 3.1 | 3.4 | 5.0 | 4.15 | 3.07 | 3.27 | 2.2 | 2.15 | 2.22 | 2.4 | 2.6 | 2.9 |
| 13 | 3.1 | 3.5 | 5.42 | 4.0 | 3.0 | 3.05 | 2.25 | 2.15 | 2.22 | 2.38 | 2.6 | 2.95 |
| 14 | 3.15 | 3.4 | 5.45 | 4.0 | 2.9 | 3.07 | 2.25 | 2.1 | 2.24 | 2.4 | 2.6 | 3.0 |
| 15 | 3.4 | 3.3 | 5.2 | 4.0 | 2.9 | 3.0 | 2.35 | 2.15 | 2.25 | 2.45 | 2.6 | 3.0 |
| 16 | 3.65 | 3.2 | 4.8 | 3.92 | 2.85 | 2.95 | 2.35 | 2.1 | 2.25 | 2.48 | 2.6 | 3.0 |
| 17 | 3.9 | 3.1 | 4.6 | 3.85 | 2.82 | 2.9 | 2.35 | 2.1 | 2.28 | 2.5 | 2.6 | 3.0 |
| 18 | 4.15 | 3.05 | 4.52 | 3.85 | 2.8 | 2.85 | 2.33 | 2.1 | 2.3 | 2.52 | 2.6 | 3.0 |
| 19 | 4.4 | 3.4 | 4.5 | 3.8 | 2.75 | 2.85 | 2.3 | 2.12 | 2.3 | 2.52 | 2.65 | 3.0 |
| 20 | 4.65 | 4.0 | 4.5 | 3.8 | 2.73 | 2.83 | 2.27 | 2.12 | 2.32 | 2.55 | 2.62 | 3.0 |
| 21 | 4.85 | 4.4 | 5.0 | 3.87 | ..... | 2.75 | 2.25 | 2.12 | 2.35 | 2.57 | 2.62 | 3.0 |
| 22 | 4.75 | 4.88 | 4.85 | 3.8 | 2.7 | 2.7 | 2.23 | 2.14 | 2.35 | 2.57 | 2.62 | 3.0 |
| 23 | 5.5 | 4.22 | 4.5 | 3.75 | 2.7 | 2.67 | 2.2 | 2.13 | 2.35 | 2.57 | 2.62 | 3.0 |
| 24 | 6.6 | 5.18 | 4.5 | 3.75 | 2.7 | 2.65 | 2.2 | 2.13 | 2.35 | 2.58 | 2.6 | 3.0 |
| 25 | 5.0 | 5.35 | 4.4 | 3.7 | 2.7 | 2.65 | 2.2 | 2.14 | 2.35 | 2.6 | 2.6 | 3.0 |
| 26 | 4.45 | 5.3 | 4.2 | 3.7 | 2.9 | 2.6 | 2.2 | 2.14 | 2.4 | 2.6 | 2.5 | 3.0 |
| 27 | 4.05 | 4.85 | 4.15 | 3.75 | 2.75 | 2.6 | 2.25 | 2.14 | 2.4 | 2.6 | 2.5 | 3.0 |
| 28 | 3.8 | 4.65 | 4.25 | 3.75 | 3.3 | 2.6 | 2.2 | 2.15 | 2.4 | 2.6 | 2.5 | 3.0 |
| 29 | 3.6 | ..... | 4.1 | 3.72 | 2.95 | 2.6 | 2.2 | 2.12 | 2.4 | 2.6 | 2.6 | 3.0 |
| 30 | 3.5 | ..... | 4.05 | 3.6 | 2.98 | 2.6 | 2.19 | 2.12 | 2.4 | 2.6 | 2.6 | 3.0 |
| 31 | 3.3 | ..... | 4.0 | ..... | 3.0 | ..... | 2.18 | 2.12 | 2.6 | 2.6 | ..... | 3.0 |

NOTE.—Ice conditions during part of January and February and all of December. Gage heights to top of ice.

*Station rating table for Malheur River at McLaughlin's bridge, near Vale, Oreg., from March 1 to April 15 and May 16 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.00 | 2 | 3.20 | 396 | 4.40 | 1,259 | 5.50 | 2,220 |
| 2.10 | 11 | 3.30 | 455 | 4.50 | 1,340 | 5.60 | 2,319 |
| 2.20 | 24 | 3.40 | 516 | 4.60 | 1,423 | 5.70 | 2,422 |
| 2.30 | 42 | 3.50 | 580 | 4.70 | 1,507 | 5.80 | 2,528 |
| 2.40 | 64 | 3.60 | 648 | 4.80 | 1,593 | 5.90 | 2,634 |
| 2.50 | 90 | 3.70 | 717 | 4.90 | 1,679 | 6.00 | 2,740 |
| 2.60 | 122 | 3.80 | 789 | 5.00 | 1,766 | 6.20 | 2,953 |
| 2.70 | 159 | 3.90 | 864 | 5.10 | 1,854 | 6.40 | 3,170 |
| 2.80 | 200 | 4.00 | 940 | 5.20 | 1,942 | 6.60 | 3,392 |
| 2.90 | 243 | 4.10 | 1,018 | 5.30 | 2,032 | 6.80 | 3,622 |
| 3.00 | 290 | 4.20 | 1,098 | 5.40 | 2,125 | 7.00 | 3,860 |
| 3.10 | 341 | 4.30 | 1,178 | | | | |

The above table is applicable only for open-channel conditions. It is based on 15 discharge measurements made during 1905. It is well defined between gage heights 2.1 feet and 5.4 feet.

NOTE.—On account of the shifting channel the rating table does not apply prior to March 1 and between April 16 and May 15. Estimates during those intervals were computed by the indirect method. In the computation missing gage heights were interpolated.

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*Estimated monthly discharge of Malheur River at McLaughlin's bridge, near Vale, Oreg., for 1905.*

[Drainage area, 3,320 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 2,980 | 260 | 751 | 46,180 | 0.226 | 0.261 |
| February | 2,080 | 210 | 726 | 40,320 | .219 | .228 |
| March | 2,170 | 940 | 1,438 | 88,420 | .433 | .499 |
| April | 3,980 | 485 | 971 | 57,780 | .292 | .326 |
| May | 475 | 160 | 283 | 17,400 | .085 | .098 |
| June | 715 | 122 | 274 | 16,300 | .083 | .093 |
| July | 122 | 22 | 47.0 | 2,890 | .014 | .016 |
| August | 24 | 11 | 15.8 | 972 | .0048 | .0055 |
| September | 64 | 13 | 37.1 | 2,208 | .011 | .012 |
| October | 122 | 44 | 87.7 | 5,392 | .026 | .030 |
| November | 140 | 90 | 120 | 7,140 | .036 | .040 |
| December | 290 | 140 | 251 | 15,430 | .076 | .088 |
| The year | 3,980 | 11 | 417 | 300,400 | .126 | 1.696 |

## MALHEUR RIVER AT HALLIDAY'S BRIDGE, NEAR ONTARIO, OREG.

This station was established December 8, 1904, by W. C. Sawyer, and discontinued July 31, 1905. It is located at Halliday's bridge, 10 miles west of Ontario, on the road to Vale, and 5 miles below the mouth of Willow Creek.

The channel is straight for 800 feet above and below the station. The right bank is high and clean. The left bank is high and clean, but overflows during very high water. The bed of the stream is composed of sand and is free from vegetation and shifting. There is but one channel at all stages.

Discharge measurements are made from the upstream side of the single-span 110-foot steel highway bridge supported upon steel caissons. The initial point for soundings is a point on the upstream side of the bridge, 20 feet outside of the center of the truss pin on the right bank.

A standard chain gage is attached to the upstream hand rail; length of chain, 23.7 feet. During 1905 the gage was read by T. W. Halliday. Bench marks were established as follows: (1) The south end of the bed plate upon which the south end of the upstream truss rests upon the concrete pier; elevation, 18.99 feet. (2) The north end of the bed plate upon which the north end of the upstream truss rests; elevation, 18.89 feet. Elevations refer to the datum of the gage.

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*Discharge measurements of Malheur River at Halliday's bridge, near Ontario, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| January 25 | E. N. Smith | 93 | 595 | 2.75 | 5.16 | 1,637 |
| January 26 | Smith and Johnson | 93 | 550 | 2.74 | 4.96 | 1,507 |
| January 30 | Sawyer and Griffin | 94 | 354 | 1.30 | 3.60 | 460 |
| February 24 | J. M. Griffin | 85 | 549 | 3.75 | 5.55 | 2,060 |
| March 1 | do | 92 | 532 | 2.77 | 4.80 | 1,475 |
| March 25 | W. C. Sawyer | 94 | 516 | 2.70 | 4.74 | 1,399 |
| March 27 | do | 94 | 448 | 2.45 | 4.41 | 1,098 |
| April 11 | Smith and Griffin | 95 | 421 | 2.41 | 4.36 | 1,014 |
| May 3 | do | 94 | 281 | 1.54 | 3.20 | 432 |
| June 21 | E. N. Smith | 92 | 167 | .53 | 2.15 | 89 |
| November 10 | R. S. Hall | 92 | 170 | .65 | 2.20 | 110 |
| December 29 | do | 90 | 106 | .71 | 2.29 | 75 |

*Daily gage height, in feet, of Malheur River at Halliday's bridge, near Ontario, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. |
|---|---|---|---|---|---|---|---|
| 1 | 2.7 | 3.2 | 4.85 | 4.15 | 3.3 | 2.38 | 1.67 |
| 2 | 2.7 | 3.1 | 4.95 | 4.22 | 3.27 | 2.25 | 1.67 |
| 3 | 2.8 | 3.0 | 4.95 | 4.58 | 3.2 | 2.2 | 1.58 |
| 4 | 2.85 | 2.9 | 4.9 | 4.77 | 3.1 | 2.27 | 1.62 |
| 5 | 2.8 | 2.9 | 5.1 | 4.53 | 3.1 | 2.55 | 1.5 |
| 6 | 2.6 | 2.8 | 5.15 | 4.27 | 3.08 | 2.55 | 1.5 |
| 7 | 2.6 | 2.7 | 5.2 | 4.18 | 2.97 | 2.65 | 1.45 |
| 8 | 2.35 | 2.6 | 5.1 | 4.25 | 2.93 | 2.8 | 1.5 |
| 9 | 2.3 | 2.7 | 4.95 | 4.32 | 2.85 | 3.0 | 1.5 |
| 10 | 2.35 | 2.5 | 4.85 | 4.35 | 2.55 | 3.47 | 1.4 |
| 11 | 2.35 | 2.4 | 5.0 | 4.37 | 2.45 | 2.97 | 1.4 |
| 12 | 2.3 | 2.8 | 5.25 | 4.23 | 2.43 | 2.85 | 1.3 |
| 13 | 2.35 | 2.5 | 5.4 | 4.12 | 2.4 | 2.7 | 1.3 |
| 14 | 2.35 | 2.65 | ..... | 4.05 | 2.35 | 2.55 | 1.4 |
| 15 | 2.35 | 2.7 | ..... | 4.0 | 2.35 | 2.4 | 1.4 |
| 16 | 2.5 | 2.8 | 5.0 | 3.83 | 2.3 | 2.3 | 1.4 |
| 17 | 2.45 | 2.7 | 4.85 | 3.8 | 2.25 | 2.25 | 1.4 |
| 18 | 3.85 | 2.7 | 4.85 | 3.75 | 2.17 | 2.25 | 1.4 |
| 19 | 3.85 | 2.7 | 4.75 | 3.75 | 2.22 | 2.5 | 1.4 |
| 20 | 4.5 | 2.8 | 4.85 | 3.75 | 2.0 | 2.17 | 1.28 |
| 21 | 4.3 | 3.25 | 5.15 | 3.75 | 1.95 | 2.1 | 1.35 |
| 22 | 3.85 | 4.75 | 5.2 | 3.7 | 1.9 | 2.03 | 1.35 |
| 23 | 5.0 | 5.15 | 5.0 | 3.65 | 1.93 | 1.92 | 1.4 |
| 24 | 7.15 | 5.65 | 4.85 | 3.6 | 1.9 | 1.85 | 1.4 |
| 25 | 5.9 | 5.85 | 4.7 | 3.55 | 1.87 | 1.85 | 1.4 |
| 26 | 4.8 | 5.6 | 4.6 | 3.48 | 1.85 | 1.83 | 1.38 |
| 27 | 4.35 | 5.35 | 4.4 | 3.45 | 2.08 | 1.77 | 1.35 |
| 28 | 3.95 | 5.05 | 4.35 | 3.47 | 2.47 | 1.68 | 1.35 |
| 29 | 3.6 | ..... | 4.25 | 3.52 | 2.5 | 1.67 | 1.35 |
| 30 | 3.4 | ..... | 4.2 | 3.38 | 2.33 | 1.73 | 1.4 |
| 31 | 3.3 | ..... | 4.2 | ..... | 2.27 | ..... | 1.4 |

NOTE.—No ice record.

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*Station rating table for Malheur River at Halliday's bridge, near Ontario, Oreg., from January 1 to July 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.40 | 9 | 2.40 | 145 | 3.40 | 481 | 4.40 | 1,098 |
| 1.50 | 17 | 2.50 | 170 | 3.50 | 525 | 4.50 | 1,174 |
| 1.60 | 26 | 2.60 | 197 | 3.60 | 575 | 4.60 | 1,252 |
| 1.70 | 36 | 2.70 | 226 | 3.70 | 630 | 4.70 | 1,332 |
| 1.80 | 47 | 2.80 | 257 | 3.80 | 689 | 4.80 | 1,413 |
| 1.90 | 59 | 2.90 | 290 | 3.90 | 752 | 4.90 | 1,495 |
| 2.00 | 72 | 3.00 | 325 | 4.00 | 817 | 5.00 | 1,578 |
| 2.10 | 87 | 3.10 | 361 | 4.10 | 885 | 5.20 | 1,748 |
| 2.20 | 104 | 3.20 | 399 | 4.20 | 954 | 5.40 | 1,925 |
| 2.30 | 123 | 3.30 | 439 | 4.30 | 1,025 | 5.60 | 2,110 |

The above table is applicable only for open-channel conditions. It is based on 12 discharge measurements made during 1904–5. It is well defined between gage heights 1.3 feet and 5.5 feet. The table has been extended beyond these limits. Above gage height 5.5 feet the rating curve is a tangent, the difference being 95 per tenth.

*Estimated monthly discharge of Malheur River at Halliday's bridge, near Ontario, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 3,582 | 123 | 635 | 39,040 |
| February | 2,158 | 170 | 663 | 36,820 |
| March | 1,925 | 954 | 1,484 | 91,250 |
| April | 1,388 | 473 | 810 | 48,200 |
| May | 439 | 53 | 183 | 11,250 |
| June | 512 | 33 | 149 | 8,866 |
| July | 33 | 3 | 11.6 | 713 |
| The period | | | | 236,100 |

## DITCHES IN MALHEUR RIVER VALLEY, OREGON.

### VINES DITCH ABOVE VALE, OREG.

This ditch diverts water from the right bank of Malheur River about 1 mile above the mouth of Malheur Canyon and 14 miles above Vale.

The gage and measuring section was half a mile below the mouth of the canyon.

*Discharge measurements of Vines ditch above Vale, Oreg., in 1904 and 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| 1904. | | *Second-feet.* |
| June 29 | M. W. Torkelson | 1.23 |
| September 23 | E. N. Smith | .60 |
| August 5 | M. W. Torkelson | .32 |
| 1905. | | |
| June 14 | E. N. Smith | 3.7 |
| June 28 | do | 1.3 |
| September 30 | Hawthorne and Griffin | 1.0 |
| October 12 | Hall and Sawyer | 1.7 |
| November 6 | R. S. Hall | .9 |

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### MALHEUR FARMERS' CANAL ABOVE VALE, OREG.

This canal diverts water from the left bank of Malheur River one-fourth mile above the mouth of Malheur Canyon and about 13 miles above Vale.

The gage and measuring section was located a short distance below the waste gate.

*Discharge measurements of Malheur Farmers' canal above Vale, Oreg., in 1904 and 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| 1904. | | *Second-feet.* |
| June 24 | Torkelson and Hawthorne | 54.0 |
| July 5 | M. W. Torkelson | 33.3 |
| July 27 | ....do | 16.6 |
| August 5 | ....do | 11.4 |
| September 23 | E. N. Smith | 5.0 |
| 1905. | | |
| May 5 | J. M. Griffin | 83.6 |
| May 16 | Smith and Griffin | 50.9 |
| June 27 | E. N. Smith | 17.4 |
| July 12 | ....do | 27.6 |
| September 30 | T. H. Hawthorne | 16.7 |
| November 6 | R. S. Hall | 10.5 |

### M'LAUGHLIN DITCH ABOVE VALE, OREG.

Water diverted from the right bank of Malheur River 1 mile below the mouth of Malheur Canyon, 12 miles above Vale, is divided one-fourth mile below the point of diversion, the left branch being the McLaughlin ditch and the right the "J. H."

The McLaughlin ditch was measured at the dividing flume.

The McLaughlin ditch was the only one above the Nevada ditch which carried water between July 15 and about September 25, the Nevada having established a prior right over all of the others.

*Discharge measurements of McLaughlin ditch above Vale, Oreg., in 1904 and 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| 1904. | | *Second-feet.* |
| June 25 | M. W. Torkelson | 10.8 |
| July 6 | ....do | 10.2 |
| July 22 | ....do | 6.2 |
| August 25 | Sawyer and Smith | 2.1 |
| September 23 | E. N. Smith | 13.2 |
| 1905. | | |
| May 16 | Smith and Griffin | 19.2 |
| June 14 | E. N. Smith | 4.2 |
| June 28 | ....do | 8.7 |
| July 12 | ....do | 5.6 |
| July 28 | ....do | 7.1 |
| August 3 | ....do | 4.0 |
| August 12 | ....do | 2.7 |
| August 22 | ....do | 2.5 |
| September 2 | ....do | 1.5 |
| September 30 | ....do | .7 |
| October 12 | W. C. Sawyer | .5 |
| November 6 | R. S. Hall | .5 |

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### "J. H." DITCH ABOVE VALE, OREG.

The gage and measuring section on the "J. H." ditch was located one-half mile below he point of diversion from the McLaughlin ditch.

*Discharge measurements of "J. H." ditch above Vale, Oreg., in 1904 and 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| 1904. | | *Second-feet.* |
| June 25 | M. W. Torkelson | 8.3 |
| July 6 | do | 9.6 |
| July 22 | do | 8.7 |
| August 5 | do | 7.1 |
| 1905. | | |
| May 16 | Smith and Griffin | 7.7 |
| June 15 | E. N. Smith | 11.1 |
| June 28 | do | 6.4 |
| July 12 | do | .3 |
| September 2 | do | 1.0 |
| September 30 | Hawthorne and Griffin | .6 |
| October 12 | W. C. Sawyer | .8 |

### LINEBARGER DITCH ABOVE VALE, OREG.

The Linebarger ditch diverted water from the right bank of Malheur River 10 miles above Vale, Oreg., from May 1 to June 14, 1905. June 14, 1905, a discharge measurement made by E. N. Smith gave a discharge of 2.7 second-feet.

### GELLERMAN & FROHMAN DITCH ABOVE VALE, OREG.

This ditch diverts water from the left bank of Malheur River about 8 miles above Vale. The gage and measuring section were located at Ricker's ranch.

*Discharge measurements of Gellerman & Frohman ditch above Vale, Oreg., in 1904 and 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| 1904. | | *Second-feet.* |
| June 25 | M. W. Torkelson | 13.5 |
| July 30 | do | 4.5 |
| September 23 | E. N. Smith | 1.6 |
| 1905. | | |
| May 5 | J. M. Griffin | 64.7 |
| May 15 | E. N. Smith | 70.7 |
| June 12 | do | 42.8 |
| June 27 | do | 25.6 |
| July 12 | do | 8.6 |
| October 12 | Sawyer and Hall | 1.1 |

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### SAND HOLLOW DITCH ABOVE VALE, OREG.

This ditch diverts water from the right bank of Malheur River 6 miles above Vale. The gaging station was located at High's ranch.

*Discharge measurements of Sand Hollow ditch above Vale, Oreg., in 1904 and 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| 1904. | | *Second-feet.* |
| June 29 | M. W. Torkelson | 12.4 |
| July 30 | ....do | 5.6 |
| August 9 | ....do | 2.9 |
| September 23 | E. N. Smith | 6.0 |
| 1905. | | |
| May 17 | Smith and Griffin | 12.6 |
| June 16 | E. N. Smith | 6.4 |
| June 29 | ....do | 7.5 |
| July 13 | ....do | 3.3 |
| October 12 | Sawyer and Hall | 5.8 |
| November 16 | R. S. Hall | 6.1 |

### HOPE MILL DITCH AT VALE, OREG.

This ditch diverts water from the left bank of Malheur River 2 miles above Vale. Its water was formerly used by a mill one-half mile south of Vale and returned to the river. Gagings were made just above the Bully Creek crossing.

*Discharge measurements of Hope Mill ditch at Vale, Oreg., in 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| | | *Second-feet.* |
| May 1 | J. M. Griffin | 12.3 |
| June 10 | E. N. Smith | 9.9 |
| June 27 | ....do | 8.2 |
| July 8 | ....do | .8 |
| October 12 | Sawyer and Hall | 5.2 |
| November 4 | R. S. Hall | 5.6 |

### NEVADA DITCH BELOW VALE, OREG.

This ditch diverts water from the right bank of Malheur River 1 mile below Vale. Measurements were made 1,000 feet below the head-gate.

*Discharge measurements of Nevada ditch below Vale, Oreg., in 1904 and 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| 1904. | | *Second-feet.* |
| July 12 | M. W. Torkelson | 107.0 |
| July 20 | ....do | 64.1 |
| August 6 | Torkelson and Smith | 46.5 |
| August 23 | Sawyer and Smith | 43.0 |
| September 7 | E. N. Smith | 34.0 |
| September 8 | ....do | 18.2 |
| September 24 | ....do | 40.9 |

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*Discharge measurements of Nevada ditch below Vale, Oreg., in 1904 and 1905*—Continued.

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| 1905. | | *Second-feet.* |
| April 25 | Smith and Griffin | 48.7 |
| May 25 | W. C. Sawyer | 69.3 |
| June 7 | E. N. Smith | 99.9 |
| July 13 | .....do | 24.0 |
| July 21 | .....do | 34.7 |
| July 29 | .....do | 27.6 |
| August 4 | .....do | 22.5 |
| August 11 | .....do | 16.9 |
| August 17 | .....do | 13.7 |
| August 29 | Smith and Eno | 14.3 |
| September 16 | G. Stubblefield | 25.9 |
| September 24 | Hawthorne and Stubblefield | 37.5 |
| October 4 | Hawthorne and Griffin | 39.2 |
| October 10 | Hall and Hawthorne | 37.2 |

*Discharge measurements of wasteways of Nevada ditch in 1905.*

McGREGOR WASTEWAY BELOW VALE, OREG.

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| | | *Second-feet.* |
| May 18 | Smith and Griffin | 0.9 |
| June 21 | E. N. Smith | 24.3 |
| October 4 | R. S. Hall | 15.9 |
| October 14 | .....do | .3 |

COTTON WASTEWAY ABOVE ONTARIO, OREG.

| | | |
|---|---|---|
| May 10 | E. N. Smith | 41.3 |
| June 21 | .....do | 6.9 |
| October 4 | Hawthorne and Griffin | 1.2 |
| October 15 | R. S. Hall | .5 |

### BROSNAN DITCH NEAR ONTARIO, OREG.

This ditch diverts water from the left bank of Malheur River 3 miles west of Ontario.

*Discharge measurements of Brosnan ditch near Ontario, Oreg., in 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| | | *Second-feet.* |
| June 7 | E. N. Smith | 0.4 |
| October 4 | Hawthorne and Griffin | 3.9 |

### BULLY CREEK ABOVE VALE, OREG.

This station was established January 27, 1905. It is near the location of the original station on Bully Creek, one-fourth mile below Warm Springs stage station, 15 miles above Vale, Oreg.



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The channel is straight for 50 feet above and 300 feet below the station. The current is swift. The right bank is high, but composed of soft soil, and may wash away for 70 feet, until the hillside is reached. The left bank is high and rocky, but may overflow a road 11 feet wide until the vertical cliff is reached. The bed of the stream is composed of gravel and is shifting. There is but one channel at all stages.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is the stream face of the bolt to which the cable is anchored at the left bank.

The gage is in two sections. The lower section, reading from 0 to 7.6 feet, is nailed in an inclined position to posts embedded in riprap on the left bank. The upper section is a vertical staff, reading from 7.6 feet to 11 feet, fastened to the cliff. During 1905 the gage was read once each day by F. O'Neill. Bench marks were established as follows:

(1) A cut on a shoulder of the cliff 11 feet upstream from the vertical portion of the gage: elevation, 9.08 feet. (2) A standard copper bolt cemented in the solid rock 2½ feet upstream from the gage on the hill side of the road; elevation, 7.61 feet. Elevations refer to the datum of the gage.

Information in regard to station formerly maintained near this point is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 428; 135, pp 211-212.
Discharge: 100, p 429; 135, p 212.
Gage height: 100, p 429; 135, p 213.

*Discharge measurements of Bully Creek above Vale, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| January 30 | Smith and Johnson | 37 | 30 | 0.86 | 2.18 | 27 |
| February 22 | Smith and Griffin | 34 | 41 | 2.07 | 2.66 | 85 |
| February 23 | E. N. Smith | 34 | 38 | 1.82 | 2.58 | 69 |
| February 25 | do | 53 | 80 | 3.66 | 3.40 | 294 |
| March 9 | Smith and Griffin | 48 | 72 | 2.98 | 3.10 | 215 |
| April 20 | E. N. Smith | 29 | 29 | 1.14 | 2.35 | 33 |
| June 9 | do | 26 | 16 | .75 | 2.00 | 12.0 |
| June 26[a] | do | 10 | 4.7 | .94 | 1.88 | 4.4 |
| July 8 | do | 8.7 | 4.3 | .39 | 1.79 | 1.7 |
| August 8[b] | do | | | | 1.69 | .3 |
| December 30[c] | R. S. Hall | 12 | 7.8 | .78 | 2.17 | 6.1 |

[a] Made one-half mile above cable. [b] Weir measurement. [c] Ice.

*Daily gage height, in feet, of Bully Creek above Vale, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2.12 | 3.3 | 2.96 | 2.0 | 2.0 | 2.0 | 1.7 | 1.64 | 1.76 | 1.8 | 1.9 |
| 2 | | 2.1 | 3.28 | 3.2 | 2.0 | 2.0 | 2.0 | 1.7 | 1.64 | 1.76 | 1.8 | 1.9 |
| 3 | | 2.1 | 3.3 | 3.0 | 2.0 | 2.0 | 2.0 | 1.7 | 1.64 | 1.76 | 1.8 | 1.9 |
| 4 | | 2.1 | 3.38 | 2.94 | 2.0 | 2.0 | 2.0 | 1.7 | 1.64 | 1.78 | 1.8 | 1.92 |
| 5 | | 2.1 | 3.62 | 2.94 | 2.0 | 2.0 | 1.9 | 1.7 | 1.64 | 1.78 | 1.82 | 1.94 |
| 6 | | 2.1 | 3.55 | 2.9 | 2.0 | 2.0 | 1.9 | 1.7 | 1.64 | 1.78 | 1.82 | 1.96 |
| 7 | | 2.6 | 3.45 | 2.8 | 2.0 | 2.0 | 1.86 | 1.7 | 1.64 | 1.78 | 1.84 | 1.96 |
| 8 | | 2.6 | 3.20 | 2.8 | 2.0 | 2.0 | 1.8 | 1.68 | 1.64 | 1.78 | 1.84 | 1.98 |
| 9 | | 2.6 | 3.1 | 2.75 | 2.0 | 2.0 | 1.8 | 1.68 | 1.64 | 1.78 | 1.84 | 1.98 |
| 10 | | 2.6 | 3.1 | 2.75 | 2.0 | 2.0 | 1.8 | 1.68 | 1.64 | 1.78 | 1.86 | 1.98 |
| 11 | | 2.6 | 3.1 | 2.7 | 2.0 | 2.0 | 1.8 | 1.68 | 1.64 | 1.8 | 1.88 | 2.0 |
| 12 | | 2.18 | 3.34 | 2.65 | 2.0 | 2.0 | 1.8 | 1.66 | 1.64 | 1.8 | 1.9 | 2.0 |

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*Daily gage height, in feet, of Bully Creek above Vale, Oreg., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | ..... | 2.3 | 3.3 | 2.6 | 2.0 | 2.0 | 1.8 | 1.66 | 1.6 | 1.8 | 1.9 | 2.0 |
| 14 | ..... | 2.2 | 3.3 | 2.6 | 2.0 | 2.0 | 1.8 | 1.66 | 1.6 | 1.8 | 1.9 | 2.02 |
| 15 | ..... | 2.2 | 3.1 | 2.6 | 2.0 | 2.0 | 1.8 | 1.64 | 1.6 | 1.8 | 1.9 | 2.02 |
| 16 | ..... | 2.3 | 2.98 | 2.56 | 2.0 | 2.0 | 1.8 | 1.64 | 1.68 | 1.8 | 1.9 | 2.02 |
| 17 | ..... | 2.42 | 2.98 | 2.5 | 2.0 | 2.0 | 1.8 | 1.64 | 1.7 | 1.8 | 1.9 | 2.04 |
| 18 | ..... | 2.22 | 3.0 | 2.46 | 2.0 | 2.0 | 1.8 | 1.64 | 1.7 | 1.8 | 1.9 | 2.04 |
| 19 | ..... | 2.2 | 3.0 | 2.4 | 2.0 | 2.0 | 1.8 | 1.64 | 1.7 | 1.8 | 1.9 | 2.04 |
| 20 | ..... | 2.2 | 3.1 | 2.35 | 2.0 | 2.0 | 1.8 | 1.64 | 1.7 | 1.8 | 1.9 | 2.06 |
| 21 | ..... | 2.45 | 3.56 | 2.26 | 2.0 | 2.0 | 1.8 | 1.64 | 1.7 | 1.8 | 1.9 | 2.06 |
| 22 | ..... | 2.7 | 3.26 | 2.22 | 2.0 | 2.0 | 1.8 | 1.64 | 1.7 | 1.8 | 1.9 | 2.08 |
| 23 | ..... | 2.7 | 3.12 | 2.22 | 2.0 | 2.0 | 1.8 | 1.64 | 1.7 | 1.8 | 1.9 | 2.08 |
| 24 | 2.36 | 3.4 | 3.2 | 2.2 | 2.0 | 2.0 | 1.8 | 1.64 | 1.7 | 1.8 | 1.9 | 2.08 |
| 25 | 2.32 | 3.4 | 3.0 | 2.18 | 2.0 | 2.0 | 1.7 | 1.64 | 1.72 | 1.8 | 1.9 | 2.1 |
| 26 | 2.21 | 3.44 | 3.0 | 2.1 | 2.0 | 2.0 | 1.7 | 1.64 | 1.72 | 1.8 | 1.9 | 2.1 |
| 27 | 2.18 | 3.4 | 2.94 | 2.04 | 2.0 | 2.0 | 1.7 | 1.64 | 1.72 | 1.8 | 1.9 | 2.12 |
| 28 | 2.23 | 3.2 | 2.9 | 2.0 | 2.0 | 2.0 | 1.7 | 1.64 | 1.74 | 1.8 | 1.9 | 2.14 |
| 29 | 2.19 | ..... | 2.9 | 2.0 | 2.0 | 2.0 | 1.7 | 1.64 | 1.74 | 1.8 | 1.9 | 2.16 |
| 30 | 2.18 | ..... | 2.9 | 2.0 | 2.0 | 2.0 | 1.7 | 1.64 | 1.74 | 1.8 | 1.9 | 2.18 |
| 31 | 2.14 | ..... | 2.95 | ..... | 2.0 | ..... | 1.7 | 1.64 | ..... | 1.8 | ..... | 2.18 |

*Station rating table for Bully Creek above Vale, Oreg., from January 24 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.60 | 0.0 | 2.20 | 24 | 2.80 | 120 | 3.30 | 261 |
| 1.70 | .3 | 2.30 | 32 | 2.90 | 146 | 3.40 | 292 |
| 1.80 | 2.0 | 2.40 | 41 | 3.00 | 174 | 3.50 | 324 |
| 1.90 | 6.0 | 2.50 | 54 | 3.10 | 202 | 3.60 | 358 |
| 2.00 | 11 | 2.60 | 72 | 3.20 | 231 | 3.70 | 394 |
| 2.10 | 17 | 2.70 | 96 | | | | |

The above table is applicable only for open-channel conditions. It is based on 11 discharge measurements made during 1905. It is well defined between gage heights 1.7 feet and 3.4 feet.

*Estimated monthly discharge of Bully Creek above Vale, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January 24–31 | 37 | 19 | 26.5 | 421 |
| February | 305 | 17 | 84.5 | 4,693 |
| March | 365 | 146 | 224 | 13,770 |
| April | 231 | 11 | 77.1 | 4,588 |
| May | 11 | 11 | 11.0 | 676 |
| June | 11 | 11 | 11.0 | 655 |
| July | 11 | .3 | 3.11 | 191 |
| August | .3 | .1 | .17 | 10 |
| September | .9 | .1 | .30 | 18 |
| October | 2 | 1.2 | 1.83 | 112 |
| November | 6 | 2 | 4.93 | 293 |
| December | 6 | 6 | 6.00 | 369 |
| The year | 365 | .1 | 37.5 | 25,800 |

NOTE.—December estimate reduced on account of ice conditions.

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## BULLY CREEK AT VALE, OREG.

This station was established April 8, 1904, by John H. Lewis, and discontinued December 31, 1905. It is located at the county highway bridge across Bully Creek just above its junction with Malheur River, at Vale, Oreg. The station is 13 miles below the former station on this creek, which was destroyed by flood and discontinued March 11, 1904. Except for a few days when the surface snow is going off, no streams enter Bully Creek between this and the old station. Five small ditches divert water during the irrigation season. The station is affected by backwater from Malheur River.

The channel is straight for about 50 feet above and 300 feet below the station and the current is swift. Both banks are high, clear, and not subject to overflow. The bed of the stream is composed of clay and sand and is shifting. There is but one channel at all stages.

Discharge measurements are made from the downstream side of the single-span bridge. The initial point for soundings is the south end of the east bridge railing.

A standard chain gage is attached to the bridge; length of chain, 17.22 feet. During 1905 the gage was read once each day by Isaac McCumsey and Z. G. Wilson. Bench marks were established as follows: (1) The top surface of the north projecting floor beam on the east side of the bridge; elevation, 15.36 feet. (2) On the north end of stone doorsill at the north door on the west side of old flour mill about 390 feet southeast of the bridge; elevation, 18.80 feet. Elevations refer to the datum of the gage.

A description of this station, with gage heights and discharge data, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 213–215.

*Discharge measurements of Bully Creek at Vale, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| January 25 | E. N. Smith | 40 | 18.9 | 0.86 | 3.70 | 16.1 |
| February 1 | P. H. Johnson | 40 | 18.5 | 1.13 | 3.70 | 20.9 |
| February 11 | J. M. Griffin | 40 | 12 | .82 | 3.60 | 9.9 |
| February 23 | Griffin and Smith | 42 | 43 | 1.72 | 4.32 | 74 |
| February 25 | J. M. Griffin | 42 | 114 | 3.91 | 5.95 | 447 |
| March 2 | E. N. Smith | 48 | 105 | 4.09 | 5.43 | 429 |
| March 3 | P. H. Johnson | 49 | 116 | 4.45 | 5.63 | 516 |
| March 9 | J. M. Griffin | 32 | 45 | 3.22 | 4.80 | 145 |
| March 23 | Smith and Johnson | 46 | 86 | 3.48 | 4.98 | 299 |
| March 30 | J. M. Griffin | 43 | 58 | 2.55 | 4.40 | 146 |
| April 11 | do | 40 | 34 | 2.68 | 3.95 | 91 |
| April 27 | do | 26 | 10.6 | 2.23 | 3.29 | 23.7 |
| June 10 | E. N. Smith | 31 | 25 | 3.00 | 3.75 | 75 |
| June 27[a] | do | 18 | 17.8 | 1.50 | 3.48 | 26.7 |
| July 29 | do | 11 | 5.7 | .82 | 3.05 | 4.7 |
| September 11 | W. C. Sawyer | 6 | 2.9 | .62 | 3.05 | 1.8 |
| October 12 | Sawyer and Hall | 10 | 2.7 | .79 | 3.05 | 2.1 |
| November 7[a] | R. S. Hall | 17 | 8.5 | .88 | 3.26 | 7.6 |
| December 27 | do | 14 | 6.2 | 1.09 | 3.17 | 6.8 |

[a] Made at different section.

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*Daily gage height, in feet, of Bully Creek at Vale, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.7 | 3.7 | 5.3 | 4.3 | 3.3 | 3.4 | 3.3 | 3.1 | 3.02 | 3.05 | 3.05 | 3.35 |
| 2 | 3.6 | 3.7 | 5.5 | 4.6 | 3.25 | 3.4 | 3.3 | 3.1 | 3.03 | 3.06 | 3.05 | 3.4 |
| 3 | 3.6 | 3.7 | 5.5 | 4.6 | 3.3 | 3.4 | 3.3 | 3.1 | 3.03 | 3.04 | 3.21 | 3.49 |
| 4 | 3.5 | 3.7 | 6.7 | 4.4 | 3.3 | 3.4 | 3.3 | 3.0 | 3.03 | 3.04 | 3.25 | 3.41 |
| 5 | 3.5 | 3.7 | 5.4 | 4.3 | 3.25 | 3.6 | 3.3 | 3.0 | 3.03 | 3.03 | 3.23 | 3.5 |
| 6 | 3.5 | 3.6 | 5.7 | 4.2 | 3.3 | 3.6 | 3.3 | 3.0 | 3.05 | 3.03 | 3.21 | 3.32 |
| 7 | 3.5 | 3.6 | 5.45 | 4.15 | 3.25 | 3.75 | 3.3 | 3.0 | 3.04 | 3.04 | 3.31 | 3.55 |
| 8 | 3.5 | 3.4 | 4.95 | 4.1 | 3.2 | 3.8 | 3.3 | 3.02 | 3.03 | 3.04 | 3.21 | 3.45 |
| 9 | 3.5 | 3.6 | 4.75 | 4.0 | 3.2 | 3.8 | 3.3 | 3.01 | 3.03 | 3.04 | 3.16 | 3.35 |
| 10 | 3.5 | 3.6 | 4.6 | 4.0 | 3.25 | 3.75 | 3.3 | 3.0 | 3.03 | 3.06 | 3.1 | 3.45 |
| 11 | 3.5 | 3.6 | 4.6 | 3.95 | 3.25 | 3.7 | 3.2 | 3.01 | 3.03 | 3.04 | 3.1 | 3.25 |
| 12 | 3.5 | 3.5 | 4.9 | 3.9 | 3.25 | 3.65 | 3.25 | 3.01 | 3.04 | 3.05 | 3.1 | 3.2 |
| 13 | 3.5 | 3.5 | 5.1 | 4.0 | 3.3 | 3.6 | 3.25 | 3.01 | 3.03 | 3.04 | 3.09 | 3.2 |
| 14 | 3.3 | 3.7 | 5.0 | 3.75 | 3.3 | 3.8 | 3.2 | 3.01 | 3.04 | 3.05 | 3.61 | 3.12 |
| 15 | 3.4 | 3.7 | 4.8 | 3.6 | 3.3 | 3.85 | 3.2 | 3.0 | 3.02 | 3.04 | 3.11 | 3.12 |
| 16 | 3.4 | 3.5 | 4.7 | 3.6 | 3.3 | 3.65 | 3.2 | 3.01 | 3.04 | 3.05 | 3.09 | 3.2 |
| 17 | 3.5 | 3.6 | 4.6 | 3.5 | 3.3 | 3.65 | 3.2 | 3.0 | 3.03 | 3.06 | 3.1 | 3.17 |
| 18 | 3.5 | 3.6 | 4.5 | 3.45 | 3.3 | 3.65 | 3.2 | 3.0 | 3.04 | 3.06 | 3.06 | 3.2 |
| 19 | 3.5 | 3.5 | 4.5 | 3.4 | 3.3 | 3.7 | 3.2 | 3.0 | 3.04 | 3.05 | 3.19 | 3.23 |
| 20 | 3.5 | 3.5 | 4.4 | 3.4 | 3.3 | 3.6 | 3.2 | 3.0 | 3.04 | 3.05 | 3.23 | 3.45 |
| 21 | 3.5 | 3.7 | 5.1 | 3.3 | 3.3 | 3.6 | 3.2 | 3.01 | 3.04 | 3.04 | 3.2 | 3.32 |
| 22 | 3.5 | 3.95 | 5.0 | 3.3 | 3.3 | 3.7 | 3.15 | 3.0 | 3.04 | 3.06 | 3.25 | 3.17 |
| 23 | 3.6 | 4.45 | 5.1 | 3.25 | 3.3 | 3.6 | 3.15 | 3.0 | 3.06 | 3.06 | 3.28 | 3.3 |
| 24 | 4.2 | 5.4 | 4.8 | 3.25 | 3.3 | 3.6 | 3.1 | 3.01 | 3.06 | 3.08 | 3.16 | 3.2 |
| 25 | 3.7 | 5.75 | 4.8 | 3.25 | 3.3 | 3.6 | 3.1 | 3.01 | 3.07 | 3.08 | 3.19 | 3.29 |
| 26 | 3.8 | 5.55 | 4.5 | 3.3 | 3.3 | 3.6 | 3.1 | 3.0 | 3.08 | 3.08 | 3.42 | 3.2 |
| 27 | 3.8 | 5.6 | 4.6 | 3.25 | 3.3 | 3.5 | 3.1 | 3.01 | 3.08 | 3.06 | 3.47 | 3.2 |
| 28 | 3.8 | 5.4 | 4.4 | 3.3 | 3.45 | 3.4 | 3.1 | 3.02 | 3.04 | 3.05 | 3.32 | 3.16 |
| 29 | 3.8 | ..... | 4.4 | 3.3 | 3.45 | 3.4 | 3.1 | 3.01 | 3.04 | 3.03 | 3.34 | 3.19 |
| 30 | 3.65 | ..... | 4.4 | 3.3 | 3.4 | 3.35 | 3.1 | 3.02 | 3.03 | 3.06 | 3.36 | 3.17 |
| 31 | 3.65 | ..... | 4.4 | ..... | 3.4 | ..... | 3.0 | 3.02 | ..... | 3.03 | ..... | 3.14 |

NOTE.—No ice record.

## WILLOW CREEK NEAR MALHEUR, OREG.

This station was established November 4, 1904, by W. C. Sawyer. It is located at Beer's ranch, about 5 miles from Malheur, on the road to Huntington, Oreg.

The channel is straight for 100 feet above and below the station, and the current is swift. Both banks are high, clean, and do not overflow. The bed of the stream is composed of rock and gravel and is free from vegetation, and permanent. There is but one channel at all stages.

Discharge measurements are made by means of a cable and car. The initial point for soundings is the eyebolt to which the cable is attached at the left bank.

A staff gage is attached to an immense bowlder at the mouth of the canyon, about one-half mile below the cable. During 1905 the gage was read once each day by S. P. Colt. The bench mark is a square chisel draft, marked with the letters "B. M." in black paint, on the top of the bowlder to which the gage is fastened, 5.4 feet upstream from the gage; elevation, 5.74 feet above the datum of the gage.

A description of this station, with gage heights and discharge data, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 215–216.

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*Discharge measurements of Willow Creek near Malheur, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet* |
| March 2[a] | W. C. Sawyer | 16 | 18.7 | 1.97 | 1.63 | 36.8 |
| March 2 | do | 15 | 15.0 | 2.61 | 1.52 | 37.6 |
| March 23 | do | 14 | 15.3 | 2.93 | 1.68 | 45.3 |
| September 14 | do | 8.2 | 4.5 | .93 | .65 | 4.2 |
| November 23 | R. S. Hall | 4.3 | 2.0 | .40 | .32 | .8 |

[a] Made by wading.

*Daily gage height, in feet, of Willow Creek near Malheur, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.0 | 1.25 | 1.54 | 0.96 | 0.56 | 0.85 | ..... | ..... | 0.8 | ..... | ..... |
| 2 | 1.0 | 1.0 | 1.52 | 1.64 | 1.0 | .78 | ..... | ..... | ..... | .8 | ..... | ..... |
| 3 | ..... | 1.0 | 1.6 | 1.6 | 1.12 | .82 | ..... | ..... | ..... | .8 | ..... | ..... |
| 4 | ..... | 1.0 | 1.5 | 1.52 | 1.12 | .94 | .55 | ..... | ..... | .8 | 0.5 | ..... |
| 5 | ..... | 1.0 | 1.7 | 1.48 | 1.06 | 1.0 | .5 | ..... | ..... | .8 | .5 | 0.5 |
| 6 | ..... | 1.0 | 1.88 | 1.36 | 1.0 | 1.04 | .5 | ..... | ..... | .8 | .5 | .5 |
| 7 | ..... | 1.2 | 2.1 | 1.32 | 1.0 | .94 | .5 | ..... | ..... | .8 | .5 | .5 |
| 8 | ..... | 1.15 | 1.94 | 1.3 | ..... | 1.14 | .5 | ..... | ..... | .85 | .5 | .5 |
| 9 | ..... | 1.0 | 1.94 | 1.24 | ..... | 1.0 | ..... | ..... | ..... | .85 | .5 | .5 |
| 10 | ..... | 1.05 | 1.96 | 1.26 | ..... | .98 | ..... | ..... | ..... | .9 | .5 | ..... |
| 11 | ..... | 1.3 | 1.86 | 1.26 | 1.1 | 1.0 | ..... | ..... | ..... | .9 | .5 | ..... |
| 12 | ..... | 1.0 | 1.84 | 1.18 | 1.14 | 1.65 | ..... | ..... | ..... | .9 | .5 | ..... |
| 13 | ..... | 1.1 | 1.8 | 1.06 | ..... | 1.25 | ..... | ..... | ..... | .9 | .45 | ..... |
| 14 | ..... | 1.2 | 1.66 | 1.0 | ..... | 1.15 | ..... | ..... | ..... | .9 | .45 | ..... |
| 15 | 0.8 | 1.3 | 1.58 | .8 | ..... | 1.1 | ..... | ..... | ..... | .9 | .45 | ..... |
| 16 | .85 | 1.2 | 1.5 | .78 | ..... | 1.0 | ..... | ..... | ..... | .9 | .45 | ..... |
| 17 | .85 | 1.3 | 1.56 | .78 | ..... | 1.0 | ..... | ..... | ..... | .9 | .4 | ..... |
| 18 | .9 | 1.4 | 1.9 | .82 | ..... | .5 | ..... | ..... | ..... | .9 | .4 | ..... |
| 19 | .9 | 1.45 | 1.62 | 1.18 | .8 | .9 | ..... | ..... | ..... | .8 | .4 | ..... |
| 20 | .95 | 1.05 | 1.8 | 1.2 | .76 | .82 | ..... | ..... | ..... | .8 | .4 | ..... |
| 21 | 1.0 | ..... | 1.66 | 1.06 | .76 | .84 | ..... | ..... | ..... | .8 | .4 | ..... |
| 22 | .95 | 1.45 | 1.74 | 1.06 | .76 | .66 | ..... | ..... | ..... | .8 | .4 | ..... |
| 23 | 1.0 | 1.45 | 1.64 | 1.0 | .9 | .52 | ..... | ..... | ..... | .8 | .35 | ..... |
| 24 | 1.05 | 1.2 | 1.58 | .86 | .74 | .54 | ..... | ..... | .8 | .8 | .35 | ..... |
| 25 | 1.05 | 1.6 | 1.54 | .85 | .84 | ..... | ..... | ..... | .8 | .8 | .35 | ..... |
| 26 | 1.1 | 1.6 | 1.44 | .98 | .84 | ..... | ..... | ..... | .8 | .8 | .35 | ..... |
| 27 | 1.05 | 1.9 | 1.38 | .94 | .84 | .92 | ..... | ..... | .8 | .85 | .35 | ..... |
| 28 | 1.1 | 1.7 | 1.36 | .82 | .8 | ..... | ..... | ..... | .8 | .85 | ..... | ..... |
| 29 | 1.0 | ..... | 1.5 | .86 | .82 | .6 | ..... | ..... | .8 | .85 | ..... | ..... |
| 30 | 1.15 | ..... | 1.4 | .94 | ..... | .65 | ..... | ..... | .8 | .85 | ..... | ..... |
| 31 | 1.0 | ..... | 1.52 | ..... | .96 | ..... | ..... | ..... | ..... | .85 | ..... | ..... |

NOTE.—Creek dry July 15 to August 24.

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*Station rating table for Willow Creek near Malheur, Oreg., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.30 | 0.5 | 0.80 | 7.0 | 1.30 | 24 | 1.80 | 53 |
| .40 | 1.2 | .90 | 9.5 | 1.40 | 29 | 1.90 | 61 |
| .50 | 2.2 | 1.00 | 12.5 | 1.50 | 34 | 2.00 | 69 |
| .60 | 3.5 | 1.10 | 16 | 1.60 | 40 | 2.10 | 78 |
| .70 | 5.0 | 1.20 | 20 | 1.70 | 46 | 2.20 | 87 |

The above table is applicable only for open-channel conditions. It is based on five discharge measurements made during 1905. It is fairly well defined.

*Estimated monthly discharge of Willow Creek near Malheur, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January 15–31 | 18.0 | 7.0 | 12.2 | 410 |
| February | 61.0 | 12.5 | 23.4 | 1,300 |
| March | 78.0 | 22.0 | 44.5 | 2,736 |
| April | 42.5 | 6.5 | 18.3 | 1,089 |
| May | 17.5 | 6.0 | 11.1 | 682 |
| June | 43.0 | 2.0 | 10.5 | 625 |
| July | 8.2 | .0 | 1.4 | 86 |
| August | 2.0 | .0 | .45 | 28 |
| September | 7.0 | 2.0 | 4.7 | 280 |
| October | 9.5 | 7.0 | 8.0 | 492 |
| November 1–27 | 6.7 | .8 | 2.0 | 106 |
| The period | | | | 7,834 |

NOTE.—Water was taken from the creek above the gage by Beer's ditch from April 8 to July 3, July 15 to August 24, and September 8–12. The estimated amount diverted by the ditch is as follows:

| | Acre-feet. | | Acre-feet. |
|---|---|---|---|
| April 8–30 | 92 | July 1–3; 15–31 | 60 |
| May | 124 | August 1–24 | 58 |
| June | 120 | September 8–12 | 20 |

The estimate for Willow Creek does not include this diversion.

## WILLOW CREEK NEAR DELL, OREG.

This station was established May 12, 1904, by H. D. Newell. It is located at a bridge at Cole's ranch near Dell, Oreg., 28 miles above Vale.

Over two-thirds of the drainage area is practically free from timber. The river bottom is irrigated and cultivated and the higher lands are covered with sagebrush. The headwaters of the creek and its tributaries drain the southern slopes of the Burnt River Mountains, which are covered with stunted pines and junipers. The Eldorado mining ditch brings a small volume of water at irregular intervals into the creek from the headwaters of Burnt River. The flow of the creek is also affected by reservoirs used for mining purposes on some of its other tributaries.

The channel is slightly curved for about 200 feet above and straight for 200 feet below the station and is somewhat obstructed by willows. The current is moderate. Both banks are low, but all the water passes between the abutments of the bridge. The bed of the stream is composed of mud and is slightly shifting. There is but one channel at all stages, broken by the bridge bents.

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Discharge measurements are made from the downstream side of the wooden highway bridge. The bridge has a single span of about 137 feet and trestle approach at each end. The initial point for soundings is the left end of the downstream hand rail.

A standard chain gage is attached to the downstream side of the bridge; length of chain, 18.06 feet. During 1905 the gage was read once each day by Emory Cole. Bench marks were established as follows: (1) A group of three spikes driven into a post at the corner of the fence about 40 feet east of the initial point; elevation, 14.92 feet. (2) A cross painted on the top of the stone of east abutment, 6.5 feet from the initial point and marked "B. M."; elevation, 14.79 feet. (3) The top of a bolt at the foot of the inclined end post of the south truss of the bridge, 20 feet from the initial point for soundings; elevation, 14.97 feet. Elevations refer to the datum of the gage.

A description of this station with gage heights, discharge data, and rating table is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 216–218.

*Discharge measurements of Willow Creek near Dell, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| January 31 | Smith and Johnson | 47 | 15 | 1.36 | 2.30 | 20.3 |
| March 3 | J. M. Griffin | 42 | 30 | 1.44 | 2.81 | 44 |
| March 4 | do | 43 | 38 | 1.54 | 3.00 | 58 |
| March 7 | Smith and Griffin | 53 | 54 | 1.81 | 3.50 | 98 |
| March 15 | Smith and Johnson | 52 | 51 | 1.83 | 3.55 | 93 |
| April 4 | Smith and Griffin | 41 | 13.2 | 1.75 | 2.68 | 23.1 |
| April 28 | do | 27 | 10.5 | 1.66 | 2.30 | 17.4 |
| June 3 | E. N. Smith | 24 | 6.0 | 1.67 | 2.10 | 11.0 |
| June 23 | do | 18 | 5.4 | 1.14 | 2.02 | 6.2 |
| July 11 | do | 5 | 1.3 | .20 | ..... | .2 |
| November 7 | R. S. Hall | 8 | 2.9 | .94 | 1.88 | 2.7 |

*Daily gage height, in feet, of Willow Creek near Dell, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.6 | ..... | ..... | 3.1 | 2.5 | 2.75 | 2.2 | 1.8 | 1.65 | 2.0 | 2.0 | 2.0 |
| 2 | 2.7 | 2.3 | 3.4 | 3.2 | 2.6 | 2.7 | 2.2 | 1.8 | 1.65 | 2.05 | 2.0 | 2.0 |
| 3 | 2.7 | 2.3 | 2.8 | 2.9 | 2.75 | 2.7 | 2.2 | 1.8 | 1.65 | 2.05 | 2.0 | 2.1 |
| 4 | 2.8 | 2.4 | 2.95 | 2.75 | 2.5 | 2.6 | 2.3 | 1.7 | 1.65 | 2.0 | 1.9 | 2.1 |
| 5 | 2.7 | 2.3 | 3.4 | 2.6 | 2.6 | 2.5 | 2.3 | 1.7 | 1.65 | 2.0 | 1.9 | 2.1 |
| 6 | 2.8 | 2.4 | 3.5 | 2.5 | 2.6 | 2.5 | 2.2 | 1.8 | 1.65 | 2.0 | 2.0 | 2.1 |
| 7 | 2.75 | 2.4 | 3.4 | 2.6 | 2.7 | 2.55 | 2.1 | 1.8 | 1.65 | 2.0 | 2.0 | 2.1 |
| 8 | 2.75 | 2.4 | 3.5 | 2.7 | 2.8 | 2.5 | 2.1 | 1.7 | 1.65 | 2.1 | 2.0 | 2.1 |
| 9 | 2.75 | 2.4 | 3.4 | 2.75 | 2.75 | 2.45 | 2.0 | 1.7 | 1.65 | 2.1 | 2.0 | 2.2 |
| 10 | 2.8 | 2.4 | 3.5 | 2.75 | 2.7 | 2.4 | 2.0 | 1.7 | 1.65 | 2.0 | 2.0 | 2.2 |
| 11 | ..... | 2.5 | 3.3 | 2.75 | 2.7 | ..... | 1.9 | 1.7 | 1.65 | 2.0 | 2.1 | 2.3 |
| 12 | 2.8 | 2.5 | ..... | 2.7 | 2.6 | ..... | 1.8 | 1.7 | 1.65 | 2.0 | 2.0 | 2.2 |
| 13 | 2.8 | 2.8 | ..... | 2.7 | 2.7 | ..... | 1.8 | 1.7 | 1.65 | 2.0 | 2.0 | 2.2 |
| 14 | 2.8 | 3.0 | 3.8 | 2.7 | 2.8 | 2.5 | 1.8 | 1.7 | 1.65 | 2.0 | 2.0 | 2.4 |
| 15 | 3.2 | 3.0 | 4.2 | 2.5 | 2.6 | 2.5 | 1.8 | 1.7 | 1.65 | 2.0 | 2.1 | 2.4 |
| 16 | 3.2 | 3.0 | ..... | 2.5 | 2.7 | ..... | 1.8 | 1.7 | 1.65 | 2.1 | 2.1 | 2.3 |
| 17 | 3.2 | 2.85 | 3.3 | 2.4 | 2.7 | 2.5 | 1.8 | 1.65 | 1.65 | 2.1 | 2.0 | 2.3 |
| 18 | 3.2 | 3.0 | 3.2 | 2.4 | 2.7 | 2.55 | 1.7 | 1.65 | 1.65 | 2.15 | 2.1 | 2.3 |
| 19 | 3.3 | 3.0 | 3.2 | 2.4 | 2.7 | 2.6 | 1.8 | 1.65 | 1.65 | 2.15 | 2.1 | ..... |
| 20 | 3.3 | 3.0 | 3.2 | 2.3 | 2.8 | 2.5 | 1.8 | 1.65 | 1.65 | 2.1 | 2.1 | ..... |
| 21 | 3.4 | 3.0 | 3.3 | 2.4 | 2.8 | 2.4 | 1.8 | 1.65 | 1.85 | 2.1 | 2.0 | ..... |
| 22 | 3.4 | 3.3 | 3.4 | 2.4 | 2.7 | 2.4 | 1.7 | 1.65 | 1.85 | 2.1 | 2.0 | ..... |

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*Daily gage height, in feet, of Willow Creek near Dell, Oreg., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 3.3 | 3.85 | 3.2 | 2.3 | 2.7 | 2.3 | 1.7 | 1.65 | 1.85 | 2.1 | 2.0 | ..... |
| 24 | 3.3 | 3.4 | 3.2 | 2.2 | 2.75 | 2.3 | 1.7 | 1.65 | 1.9 | 2.1 | 1.9 | ..... |
| 25 | 3.3 | 3.4 | 3.2 | 2.3 | 2.7 | 2.3 | 1.8 | 1.65 | 2.0 | 2.1 | 2.0 | ..... |
| 26 | 3.4 | 3.4 | 3.2 | 2.3 | 2.8 | 2.3 | 1.7 | 1.65 | 2.0 | 1.9 | 2.1 | ..... |
| 27 | 3.4 | 3.6 | 3.2 | 2.4 | 2.7 | 2.3 | 1.7 | 1.65 | 2.05 | 1.9 | 2.1 | ..... |
| 28 | 3.4 | 3.5 | 3.3 | 2.5 | 2.75 | 2.2 | 1.8 | 1.65 | 2.0 | 2.1 | 2.1 | ..... |
| 29 | 3.0 | ..... | 3.3 | 2.5 | 3.0 | 2.2 | 1.8 | 1.65 | 2.05 | 1.9 | 2.0 | ..... |
| 30 | 2.7 | ..... | 3.2 | 2.4 | ..... | 2.3 | 1.7 | 1.65 | 1.95 | 2.0 | 2.1 | ..... |
| 31 | ..... | ..... | 3.2 | ..... | 2.8 | ..... | 1.7 | 1.65 | ..... | 2.0 | ..... | ..... |

NOTE.—No ice record.

*Station rating table for Willow Creek near Dell, Oreg., from January 1 to March 13 and April 6 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.70 | 0.5 | 2.30 | 18 | 2.90 | 51 | 3.50 | 98 |
| 1.80 | 1 | 2.40 | 22 | 3.00 | 58 | 3.60 | 107 |
| 1.90 | 3 | 2.50 | 27 | 3.10 | 65 | 3.70 | 116 |
| 2.00 | 6 | 2.60 | 33 | 3.20 | 73 | 3.80 | 126 |
| 2.10 | 10 | 2.70 | 39 | 3.30 | 81 | 3.90 | 136 |
| 2.20 | 14 | 2.80 | 45 | 3.40 | 89 | 4.00 | 146 |

The above table is applicable only for open-channel conditions. It is based on 10 discharge measurements made during 1905. It is well defined below gage height 5 feet. On account of a change in the channel, which lasted from March 14 to April 5, a supplementary rating table is required during that period.

*Station rating table for Willow Creek near Dell, Oreg., from March 14 to April 5, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.60 | 19 | 3.10 | 53 | 3.50 | 88 | 3.90 | 130 |
| 2.70 | 25 | 3.20 | 61 | 3.60 | 98 | 4.00 | 142 |
| 2.80 | 31 | 3.30 | 70 | 3.70 | 108 | 4.10 | 154 |
| 2.90 | 38 | 3.40 | 79 | 3.80 | 119 | 4.20 | 166 |
| 3.00 | 45 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on two discharge measurements made in March and April, 1905. It is fairly well defined.

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*Estimated monthly discharge of Willow Creek near Dell, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 89 | 18 | 59.6 | 3,665 |
| February | 131 | 18 | 51.5 | 2,860 |
| March | 166 | 45 | 80.5 | 4,950 |
| April | 61 | 14 | 29.6 | 1,761 |
| May | 58 | 27 | 39.8 | 2,447 |
| June | 42 | 14 | 25.4 | 1,511 |
| July | 18 | .5 | 4.6 | 283 |
| August | 1 | .0 | .34 | 21 |
| September | 8 | .0 | 1.5 | 89 |
| October | 12 | 3 | 7.3 | 449 |
| November | 10 | 3 | 7.0 | 417 |
| The period | | | | 18,450 |

NOTE.—Discharge was interpolated for missing gage heights.

## DITCHES IN WILLOW CREEK VALLEY NEAR VALE, OREG.

The following measurements were made of ditches diverting water from Willow Creek below Cole's ranch, 28 miles above Vale:

*Discharge measurements of ditches in Willow Creek Valley above Vale, Oreg.*

COLE'S DITCH NEAR DELL.

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| 1904. | | *Second-feet.* |
| July 8 | M. W. Torkelson | 1.9 |
| August 3 | do | 1.4 |
| September 3 | E. N. Smith | 1.5 |
| 1905. | | |
| April 27 | Smith and Griffin | 7.0 |
| June 2 | E. N. Smith | 3.1 |
| July 10 | do | .7 |
| September 28 | J. M. Griffin | .5 |
| November 8 | R. S. Hall | .14 |

COMPANY DITCH.

| | | |
|---|---|---|
| 1904. | | |
| July 8 | M. W. Torkelson | 8.5 |
| August 3 | do | .3 |
| September 3 | E. N. Smith | 1.2 |
| 1905. | | |
| April 28 | Smith and Griffin | 15.4 |
| June 3 | E. N. Smith | 12.6 |
| June 23 | do | 8.1 |
| July 11 | do | .3 |
| September 28 | J. M. Griffin | 4.5 |

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*Discharge measurements of ditches in Willow Creek Valley above Vale, Oreg.*—Continued.

PATRICK FAULKNER DITCH.

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| | | *Second-feet.* |
| 1904. | | |
| September 3... | E. N. Smith | 0.4 |
| 1905. | | |
| April 29..... | Smith and Griffin | 1.5 |
| June 1..... | E. N. Smith | 1.4 |
| July 11..... | ....do | .76 |
| August 10..... | ....do | .09 |

LARRY FAULKNER DITCH.

| | | |
|---|---|---|
| 1905. | | |
| April 29..... | Smith and Griffin | 3.3 |

GRAY DITCH.

| | | |
|---|---|---|
| 1905. | | |
| August 9..... | E. N. Smith | 4.1 |

HARRIS DITCH.

| | | |
|---|---|---|
| 1905. | | |
| April 29..... | Smith and Griffin | 0.5 |

LOGAN DITCH.

| | | |
|---|---|---|
| 1904. | | |
| August 3..... | M. W. Torkelson | 1.2 |
| 1905. | | |
| April 28..... | E. N. Smith | 5.4 |
| June 2..... | ....do | .22 |
| July 11..... | ....do | .33 |
| September 28.. | J. M. Griffin | .67 |

BECKER CREEK LOGAN DITCH.

| | | |
|---|---|---|
| 1905. | | |
| April 28..... | Smith and Griffin | 0.5 |

NORWOOD DITCH.

| | | |
|---|---|---|
| 1905. | | |
| April 27..... | Smith and Griffin | 2.5 |
| June 2..... | E. N. Smith | .37 |
| June 23..... | ....do | .3 |

PETERSON AND TETER DITCH.

| | | |
|---|---|---|
| 1905. | | |
| April 29..... | E. N. Smith | 3.1 |

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*Discharge measurements of ditches in Willow Creek Valley above Vale, Oreg.*—Continued.

SCOTT DITCH.

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| 1904. | | *Second-feet.* |
| July 7 | M. W. Torkelson[a] | 1.9 |
| July 7 | ....do.[b] | 5.2 |
| 1905. | | |
| April 28 | Smith and Griffin[c] | 3.8 |
| June 2 | E. N. Smith[c] | 1.3 |
| June 23 | ....do.[c] | 1.6 |

TURNER DITCH.

| | | |
|---|---|---|
| 1904. | | |
| August 3 | M. W. Torkelson | 2.2 |
| September 3 | E. N. Smith | 1.8 |
| 1905. | | |
| April 28 | Smith and Griffin | 1.4 |
| June 3 | E. N. Smith | 3.1 |
| July 11 | ....do | .27 |
| June 23 | ....do | 1.2 |
| August 25 | ....do | .6 |

[a] Upper Scott ditch. [b] Lower Scott ditch. [c] Above diversion.

## POWDER RIVER NEAR BAKER CITY, OREG.

This station was established December 20, 1903, by John H. Lewis. It is located 10 miles above Baker City, Oreg., and one-fourth mile below Salisbury, a station on the Sumpter Valley Railway. The station is above all important diversions and above the point where the river enters the valley which surrounds Baker City. Above the station the river drains the eastern slope of a spur of the Blue Mountains. A large portion of the area has been cleared of timber.

The channel is straight for about 75 feet above and 100 feet below the station, and the current is swift. Both banks are low, timbered, and liable to overflow. The bed of the stream is composed of gravel and is free from vegetation and permanent. There is but one channel at all stages.

Discharge measurements are made from a wagon bridge having a single span of about 50 feet. The initial point for soundings is at the left end of the bridge.

A staff gage is fastened vertically to a tree on the left bank, about 400 feet below the house of R. M. Garrett, who during 1905 read the gage twice each day. The bench mark is a group of three 30-penny nails driven into a large cottonwood tree which stands on the left bank of the stream 35 feet below the gage and 6 feet above the end of the bridge; elevation, 8.00 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 430–431; 135, p 221.
Discharge: 100, p 431; 135, p 222.
Discharge, monthly: 135, p 223.
Gage heights: 100, p 431; 135, p 222.
Rating table: 135, p 223.

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*Discharge measurements of Powder River near Baker City, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| March 28 | W. C. Sawyer | 40 | 54.0 | 2.78 | 2.94 | 151 |
| May 23 | do | 40 | 58.0 | 2.97 | 3.10 | 172 |
| August 1 | do | 25 | 15.1 | 1.00 | 1.91 | 15.3 |
| November 13[a] | R. S. Hall | 30 | 26.3 | .43 | 2.11 | 11.3 |

[a] River partly covered with ice.

*Daily gage height, in feet, of Powder River near Baker City, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.15 | 2.15 | 2.7 | 2.85 | 3.35 | 3.55 | 2.45 | 2.05 | 1.65 | 1.95 | 2.05 | 2.1 |
| 2 | 2.05 | 2.1 | 2.6 | 2.85 | 3.4 | 3.45 | 2.55 | 2.0 | 1.65 | 1.95 | 2.1 | 2.05 |
| 3 | 1.95 | 2.1 | 2.7 | 2.95 | 3.4 | 3.45 | 2.45 | 1.9 | 1.6 | 1.85 | 2.05 | 2.0 |
| 4 | 2.0 | 2.25 | 3.0 | 3.05 | 3.25 | 3.45 | 2.35 | 1.85 | 1.7 | 2.05 | 2.05 | 2.05 |
| 5 | 2.0 | 2.25 | 2.95 | 2.95 | 3.15 | 3.45 | 2.25 | 1.8 | 1.6 | 1.95 | 2.05 | 2.1 |
| 6 | 2.0 | 2.05 | 3.05 | 2.95 | 3.05 | 3.3 | 2.15 | 1.8 | 1.55 | 1.95 | 2.0 | 2.1 |
| 7 | 2.0 | 2.15 | 3.05 | 3.15 | 3.25 | 3.2 | 1.95 | 1.8 | 1.55 | 2.0 | 2.1 | 2.1 |
| 8 | 1.95 | 2.2 | 2.95 | 3.35 | 3.25 | 3.25 | 1.9 | 1.85 | 1.6 | 2.05 | 2.05 | 2.05 |
| 9 | 1.9 | 2.15 | 2.95 | 3.35 | 3.15 | 3.25 | 1.75 | 1.75 | 1.6 | 2.0 | 2.05 | 2.05 |
| 10 | 1.9 | 2.05 | 3.05 | 3.25 | 3.05 | 3.15 | 1.95 | 1.85 | 1.6 | 2.05 | 2.05 | 2.0 |
| 11 | 1.9 | 2.0 | 3.0 | 3.15 | 3.05 | 3.1 | 2.15 | 1.85 | 1.55 | 2.05 | 2.05 | 2.1 |
| 12 | 1.9 | 2.15 | 3.3 | 3.2 | 3.05 | 3.05 | 2.0 | 1.85 | 1.55 | 2.05 | 2.0 | 2.1 |
| 13 | 1.9 | 2.15 | 3.35 | 3.05 | 3.05 | 3.0 | 2.05 | 1.8 | 1.55 | 2.05 | 2.1 | 2.1 |
| 14 | 1.9 | 2.25 | 3.25 | 3.05 | 3.0 | 3.05 | 2.05 | 1.85 | 1.55 | 1.85 | 2.1 | 2.1 |
| 15 | 1.9 | 2.25 | 3.45 | 3.15 | 2.95 | 3.05 | 2.05 | 1.85 | 1.55 | 2.0 | 2.0 | 2.1 |
| 16 | 2.0 | 2.25 | 3.45 | 3.05 | 3.05 | 2.95 | 2.05 | 1.8 | 1.55 | 1.95 | 2.0 | 2.1 |
| 17 | 2.15 | 2.3 | 3.45 | 3.15 | 3.25 | 2.85 | 2.0 | 1.85 | 1.6 | 2.0 | 2.05 | 2.05 |
| 18 | 2.25 | 2.35 | 3.35 | 3.05 | 3.35 | 2.85 | 2.05 | 1.75 | 1.55 | 1.95 | 2.1 | 2.05 |
| 19 | 2.35 | 2.25 | 3.25 | 3.15 | 3.25 | 2.75 | 1.85 | 1.75 | 1.55 | 1.95 | 2.1 | 2.05 |
| 20 | 2.25 | 2.25 | 3.15 | 3.1 | 3.25 | 2.85 | 1.85 | 1.7 | 1.6 | 1.95 | 2.05 | 2.1 |
| 21 | 2.35 | 2.25 | 3.15 | 3.1 | 3.25 | 2.75 | 1.95 | 1.65 | 1.6 | 2.1 | 2.0 | 2.1 |
| 22 | 2.35 | 2.3 | 3.15 | 3.1 | 3.25 | 2.6 | 1.95 | 1.65 | 1.75 | 2.1 | 2.0 | 2.1 |
| 23 | 2.4 | 2.4 | 3.1 | 3.1 | 3.10 | 2.65 | 2.05 | 1.6 | 1.7 | 2.05 | 2.05 | 2.1 |
| 24 | 2.3 | 2.35 | 3.15 | 3.2 | 3.15 | 2.65 | 2.0 | 1.65 | 1.65 | 2.05 | 2.05 | 2.1 |
| 25 | 2.45 | 2.25 | 3.05 | 3.25 | 3.05 | 2.65 | 1.85 | 1.7 | 1.65 | 2.0 | 2.05 | 2.0 |
| 26 | 2.35 | 2.35 | 2.95 | 3.4 | 3.05 | 2.6 | 1.9 | 1.65 | 1.75 | 2.05 | 2.05 | 2.0 |
| 27 | 2.35 | 2.55 | 2.9 | 3.45 | 3.1 | 2.55 | 1.9 | 1.6 | 1.65 | 2.0 | 2.05 | 2.0 |
| 28 | 2.2 | 2.4 | 2.9 | 3.45 | 3.15 | 2.55 | 1.85 | 1.65 | 1.75 | 2.1 | 2.05 | 2.0 |
| 29 | 2.15 | ..... | 2.85 | 3.35 | 3.0 | 2.6 | 1.85 | 1.65 | 1.75 | 2.1 | 2.1 | 2.05 |
| 30 | 2.2 | ..... | 2.85 | 3.45 | 3.15 | 2.45 | 1.9 | 1.65 | 1.95 | 2.05 | 2.1 | 2.1 |
| 31 | 2.15 | ..... | 2.65 | ..... | 3.35 | ..... | 2.05 | 1.6 | ..... | 2.05 | ..... | 2.1 |

NOTE.—Ice conditions during January, February, November, and December. Gage heights are to water surface. They are only approximate owing to changing ice conditions.

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*Station rating table for Powder River near Baker City, Oreg., from January 1, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.30 | 2 | 2.80 | 120 | 4.30 | 571 | 5.70 | 1,048 |
| 1.40 | 2.5 | 2.90 | 140 | 4.40 | 605 | 5.80 | 1,082 |
| 1.50 | 3 | 3.00 | 161 | 4.50 | 639 | 5.90 | 1,116 |
| 1.60 | 4 | 3.10 | 184 | 4.60 | 673 | 6.00 | 1,150 |
| 1.70 | 7 | 3.20 | 209 | 4.70 | 707 | 6.20 | 1,218 |
| 1.80 | 11 | 3.30 | 237 | 4.80 | 741 | 6.40 | 1,286 |
| 1.90 | 16 | 3.40 | 267 | 4.90 | 775 | 6.60 | 1,354 |
| 2.00 | 22 | 3.50 | 299 | 5.00 | 810 | 6.80 | 1,422 |
| 2.10 | 30 | 3.60 | 333 | 5.10 | 844 | 7.00 | 1,490 |
| 2.20 | 38 | 3.70 | 367 | 5.20 | 878 | 7.20 | 1,558 |
| 2.30 | 48 | 3.80 | 401 | 5.30 | 912 | 7.40 | 1,626 |
| 2.40 | 60 | 3.90 | 435 | 5.40 | 946 | 7.60 | 1,694 |
| 2.50 | 72 | 4.00 | 469 | 5.50 | 980 | 7.80 | 1,762 |
| 2.60 | 86 | 4.10 | 503 | 5.60 | 1,014 | 8.00 | 1,830 |
| 2.70 | 102 | 4.20 | 537 | | | | |

The above table is applicable only for open-channel conditions. It is based on 11 discharge measurements made during 1903–1905. It is fairly well defined above gage height 1.7 feet.

*Estimated monthly discharge of Powder River near Baker City, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| March | 283 | 86 | 179 | 11,010 |
| April | 283 | 130 | 201 | 11,960 |
| May | 267 | 150 | 202 | 12,420 |
| June | 316 | 66 | 164 | 9,759 |
| July | 79 | 9 | 27.0 | 1,660 |
| August | 26 | 4 | 10.0 | 615 |
| September | 19 | 3.5 | 5.4 | 321 |
| October | 30 | 13 | 23.1 | 1,420 |
| The period | | | | 49,160 |

NOTE.—Reliable estimates could not be prepared during January, February, November, and December on account of ice conditions.

## GRANDE RONDE RIVER AT HILGARD, OREG.

This station was established November 6, 1903, by John H. Lewis. It is located at the county highway bridge one-half mile below the Oregon Railroad and Navigation Company station at Hilgard, Oreg. It is just below the mouth of Five Points Creek, which is the first important tributary above Grande Ronde Valley. There are two dams about 20 miles upstream, used to flood the river during the log-driving season. The drainage area above this station lies almost wholly in the northern and eastern slopes of the Blue Mountains, the greater portion being well timbered.

The channel is straight for 100 feet above and 200 feet below the station. At ordinary stages all the water passes under the right span, which has a length of 70 feet from the right abutment to the middle pier. At high stages the water also passes under the shorter span, which has a length of 52 feet from the left abutment to the middle pier. The right bank is low, but is not liable to overflow. The left bank is low and will overflow only at

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a few points above the bridge. The bed of the stream is composed of sand and clay and is free from vegetation and bowlders. It is permanent under the main span, but is liable to shift in the high-water channel under the shorter span.

Discharge measurements are made from the downstream side of the two-span bridge, which is supported by two timber-crib abutments and by one middle crib pier. The initial point for soundings is at a point where the end post meets the lower chord of the bridge on the right bank. It is directly over the vertical outer edge of the abutment.

The gage is a staff driven vertically into the ground at the downstream end of the middle bridge pier and bolted at the upper end to the log pier. During 1905 the gage was read once daily at ordinary stages and twice daily during floods by Jay Hawes. Bench marks were established as follows: (1) The head of a bolt through the lower chord of the bridge, 7.5 feet from the timber to which the gage is attached; elevation, 13.80 feet. (2) A square chisel draft and the letters "U. S. B. M." cut in the top of a rock 200 feet from the right bank, 150 feet upstream from the bridge; elevation, 12.81 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 420; 135, p 224.
Discharge: 100, p 420; 135, p 225.
Discharge, monthly: 135, p 226.
Gage heights: 100, p 421; 135, p 225.
Rating table: 135, p 226.

*Discharge measurements of Grande Ronde River at Hilgard, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| March 4 | W. C. Sawyer | 69 | 260 | 1.91 | 3.95 | 498 |
| May 16 | do | 70 | 293 | 2.17 | 4.10 | 636 |
| August 2 [a] | do | 28 | 35 | 1.27 | 2.86 | 44.1 |
| November 14 | R. S. Hall | 67 | 188 | .26 | 2.86 | 48.9 |

[a] Made at different section.

*Daily gage height, in feet, of Grande Ronde River at Hilgard, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.0 | 3.1 | 3.8 | 3.95 | 4.3 | 3.8 | 2.2 | 2.85 | 2.65 | 2.7 | 2.85 | 2.8 |
| 2 | 3.0 | 3.1 | 4.0 | 3.92 | 4.1 | 3.9 | 2.3 | 2.85 | 2.6 | [a] 3.7 | 2.8 | 2.85 |
| 3 | 3.05 | 3.0 | 4.0 | 4.0 | 4.3 | 3.9 | 3.0 | 2.85 | 2.6 | 2.85 | 2.8 | 2.8 |
| 4 | 2.95 | 3.0 | 4.0 | 4.0 | 5.0 | 3.9 | 3.1 | 2.85 | 2.62 | 2.7 | 2.8 | 2.8 |
| 5 | 2.9 | 3.0 | 3.95 | 4.1 | 5.2 | 3.85 | 3.2 | 2.85 | 2.8 | 2.7 | [a] 3.8 | 2.75 |
| 6 | 2.9 | 3.0 | 3.92 | 4.1 | 5.3 | 3.75 | 3.1 | 2.85 | 2.7 | 2.7 | 2.8 | 2.75 |
| 7 | 2.9 | 3.05 | 3.9 | 4.15 | [a] 6.8 | 3.7 | 3.1 | 2.85 | 2.7 | 2.7 | 2.75 | 2.8 |
| 8 | 3.0 | 3.02 | 3.85 | 4.05 | 5.8 | 3.72 | 3.1 | 2.85 | 2.7 | 2.7 | 2.8 | 2.8 |
| 9 | 3.0 | 3.0 | 3.85 | 4.0 | 5.2 | 3.75 | 3.0 | 2.85 | 2.7 | 2.75 | 2.85 | 2.8 |
| 10 | 2.95 | 2.9 | 3.9 | 3.95 | 5.5 | 3.7 | 2.75 | 2.85 | 2.65 | 2.75 | 2.85 | 2.8 |
| 11 | 2.92 | 2.8 | 3.6 | 4.0 | [a] 6.2 | 3.7 | 2.75 | 2.85 | 2.65 | 2.75 | 2.85 | 2.85 |
| 12 | 2.85 | 3.1 | 3.6 | 4.1 | 5.8 | 3.65 | 2.75 | 2.85 | 2.7 | [a] 3.3 | 2.75 | 2.85 |
| 13 | 3.0 | 3.1 | 3.65 | 4.1 | 5.6 | 3.65 | 2.85 | 2.85 | 2.68 | 2.75 | 2.7 | 2.85 |
| 14 | 3.05 | 3.1 | 3.8 | 3.9 | 5.4 | 3.68 | 2.95 | 2.85 | 2.7 | 2.75 | 2.7 | 2.8 |
| 15 | 3.0 | 3.2 | 3.85 | 3.85 | 5.2 | 3.4 | 2.9 | 2.85 | 2.7 | 2.75 | 2.8 | 2.8 |
| 16 | 3.0 | 3.3 | 3.67 | 3.85 | 4.1 | 3.1 | 2.9 | 2.85 | 2.72 | 2.8 | 2.8 | 2.85 |
| 17 | 3.0 | 3.3 | 3.65 | 3.82 | 4.3 | 3.0 | 2.95 | 2.85 | 2.6 | 2.85 | 2.8 | 2.8 |
| 18 | 3.0 | 3.3 | 3.6 | 3.9 | 4.1 | 3.0 | 2.98 | 2.85 | 2.6 | 2.85 | [a] 3.0 | 2.8 |

[a] River flooded to run logs. Water stored during preceding night. No change in normal flow.

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*Daily gage height, in feet, of Grande Ronde River at Hilgard, Oreg., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 3.0 | 3.2 | 3.62 | 3.85 | 4.1 | 3.05 | 2.99 | 2.85 | 2.65 | 2.85 | 2.85 | 2.8 |
| 20 | 3.0 | 3.2 | 3.7 | 3.85 | 4.1 | 3.05 | 2.9 | 2.8 | 2.65 | 2.8 | 2.8 | 2.8 |
| 21 | 3.0 | 3.35 | 3.97 | 4.0 | 4.1 | 2.7 | 2.85 | 2.85 | 2.7 | 2.8 | 2.8 | 2.8 |
| 22 | 3.0 | 3.45 | 3.97 | 4.25 | 4.0 | 2.5 | 2.85 | 2.85 | 2.7 | 2.85 | 2.75 | 2.8 |
| 23 | 3.1 | 3.6 | 3.95 | 4.0 | 4.0 | 2.3 | 2.8 | 2.8 | 2.65 | 2.8 | 2.75 | 2.9 |
| 24 | 3.3 | 3.45 | 3.8 | 4.0 | 4.0 | 2.3 | 2.8 | 2.8 | 2.7 | 2.85 | 2.8 | 2.9 |
| 25 | 3.3 | 3.7 | 3.75 | 4.1 | 3.9 | 2.2 | 2.8 | 2.85 | 2.7 | 2.85 | 2.8 | 2.85 |
| 26 | 3.25 | 3.9 | 4.1 | [a] 4.65 | 3.85 | 2.2 | 2.8 | 2.8 | 2.7 | 2.85 | 2.8 | 2.9 |
| 27 | 3.35 | 3.85 | 4.1 | 4.25 | 3.8 | 3.3 | 2.8 | 2.8 | 2.72 | [a] 3.1 | 2.85 | 3.1 |
| 28 | 3.5 | 3.8 | 4.0 | 4.3 | 3.8 | 3.25 | 2.85 | 2.8 | 2.7 | 2.85 | 2.85 | 3.1 |
| 29 | 3.4 | ..... | 4.0 | 4.55 | 3.8 | 2.35 | 2.85 | 2.75 | 2.7 | 2.8 | 2.85 | 3.1 |
| 30 | 3.2 | ..... | 3.9 | 4.5 | 3.8 | 2.2 | 2.85 | 2.7 | 2.68 | 2.75 | 2.85 | 3.1 |
| 31 | 3.1 | ..... | 3.9 | ..... | 3.75 | ..... | 2.85 | 2.7 | ..... | 2.75 | ..... | 3.1 |

[a] River flooded to run logs. Water stored during preceding night. No change in normal flow.

NOTE.—Ice conditions during part of January, February, and December.

*Station rating table for Grande Ronde River at Hilgard, Oreg., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.20 | 3 | 3.40 | 228 | 4.60 | 1,070 | 5.80 | 2,466 |
| 2.30 | 5 | 3.50 | 272 | 4.70 | 1,170 | 5.90 | 2,592 |
| 2.40 | 8 | 3.60 | 320 | 4.80 | 1,275 | 6.00 | 2,717 |
| 2.50 | 12 | 3.70 | 370 | 4.90 | 1,384 | 6.20 | 2,969 |
| 2.60 | 18 | 3.80 | 425 | 5.00 | 1,495 | 6.40 | 3,221 |
| 2.70 | 26 | 3.90 | 485 | 5.10 | 1,608 | 6.60 | 3,473 |
| 2.80 | 38 | 4.00 | 550 | 5.20 | 1,725 | 6.80 | 3,725 |
| 2.90 | 58 | 4.10 | 620 | 5.30 | 1,846 | 7.00 | 3,977 |
| 3.00 | 84 | 4.20 | 700 | 5.40 | 1,968 | 7.20 | 4,229 |
| 3.10 | 114 | 4.30 | 785 | 5.50 | 2,092 | 7.40 | 4,481 |
| 3.20 | 148 | 4.40 | 875 | 5.60 | 2,216 | 7.60 | 4,733 |
| 3.30 | 186 | 4.50 | 970 | 5.70 | 2,341 | 7.80 | 4,985 |

The above table is applicable only for open-channel conditions. It is based on nine discharge measurements made during 1904–5. It is well defined between gage heights 2.8 feet and 5.5 feet. Below gage height 2.8 feet the table is very uncertain. The table has been extended beyond these limits. Above gage heights 4.7 feet the table is the same as in 1904.

*Estimated monthly discharge of Grande Ronde River at Hilgard, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 272 | 48 | 108 | 6,641 |
| February | 485 | 38 | 180 | 9,997 |
| March | 620 | 320 | 461 | 28,350 |
| April | 1,020 | 440 | 597 | 35,520 |
| May | 2,466 | 398 | 1,127 | 69,300 |
| June | 485 | 3 | 227 | 13,510 |
| July | 148 | 3 | 60.6 | 3,726 |
| August | 48 | 26 | 44.1 | 2,712 |
| September | 38 | 18 | 24.3 | 1,446 |
| October | 48 | 26 | 37.1 | 2,281 |
| November | 48 | 26 | 39.6 | 2,356 |
| December | 114 | 32 | 54.6 | 3,357 |
| The year | 3,725 | 3 | 247 | 179,200 |

*.—Extremely low gage heights probably due to storage above.

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## GRANDE RONDE RIVER AT ELGIN, OREG.

This station was established November 20, 1903, by John H. Lewis. It is located at the county bridge on the road from Elgin to Wallowa, Oreg., and is one-fourth mile east of the railroad station. It is at the lower end of the Grande Ronde Valley, a broad, flat, fertile valley in which much of the water is used for the irrigation of fruit, sugar beets, and other crops. The valley contains over 200 square miles, its width being about 12 miles and its length more than 20. Its upper end is about 6 miles below the Hilgard station. Some water is received from a number of small streams rising in the hills which surround the valley.

The channel is curved above a point 30 feet above the bridge, and is straight for 200 feet below. The right bank is high, rocky, free from vegetation, and will not overflow. The left bank is low, free from vegetation, and will overflow only under the trestle approach. The bed of the stream is uneven, covered with large bowlders, and is free from vegetation. It is not liable to shift. The channel is broken by the piers and the trestle bent at high water.

Discharge measurements are made from the downstream side of the bridge, which has a span between piers of 100 feet, with 130 feet of trestle approach from the left bank and 30 feet of approach from the right bank. The initial point for soundings is on the right bank directly over the center of the bent, 30 feet from the caisson.

A standard chain gage is attached to the upstream side of the bridge, near the center of the stream; length of chain, 22.00 feet. During 1905 the gage was read once each day by John Graham. The bench mark is the top surface of the steel caisson directly over the gage; elevation, 15.14 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of United States Geological Survey:

Description: 100, p 419; 135, pp 226–227.
Discharge: 100, p 419; 135, p 227.
Discharge, monthly: 135, p 229.
Gage heights: 100, p 419; 135, pp 227–228.
Rating table: 135, p 228.

*Discharge measurements of Grande Ronde River at Elgin, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 1 | W. C. Sawyer | 86 | 336 | 2.60 | 3.25 | 872 |
| May 22 | do | 92 | 356 | 2.81 | 3.48 | 1,000 |
| September 21 | do | 32 | 27 | 1.37 | 1.48 | 37.5 |
| November 30 | R. S. Hall | 88 | 221 | .36 | 1.74 | 80 |



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*Daily gage height, in feet, of Grande Ronde River at Elgin, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.6 | 2.25 | 3.0 | 3.25 | 3.5 | 3.2 | 2.3 | 1.4 | 1.35 | 1.7 | 1.7 | 1.7 |
| 2 | 2.45 | 2.4 | 2.95 | 3.2 | 3.5 | 3.25 | 2.3 | 1.4 | 1.35 | 1.65 | 1.7 | 1.75 |
| 3 | 2.45 | 2.1 | 3.05 | 3.35 | 3.55 | 3.25 | 2.2 | 1.35 | 1.35 | 1.65 | 1.7 | 1.7 |
| 4 | 2.25 | 2.05 | 3.1 | 3.3 | 3.75 | 3.25 | 2.15 | 1.35 | 1.35 | 1.65 | 1.7 | 1.75 |
| 5 | 2.25 | 2.05 | 3.1 | 3.3 | 4.0 | 3.3 | ..... | 1.35 | 1.35 | 1.65 | 1.7 | 1.8 |
| 6 | 2.2 | 2.05 | 3.05 | 3.5 | 4.05 | 3.3 | 2.1 | 1.35 | 1.35 | 1.7 | 1.75 | 1.8 |
| 7 | 2.1 | 2.0 | 3.05 | 3.5 | 4.05 | 3.3 | 2.05 | 1.35 | 1.35 | 1.65 | 1.85 | 1.8 |
| 8 | 2.1 | 1.9 | 2.95 | 3.6 | 4.16 | 3.2 | 1.9 | 1.35 | 1.35 | 1.65 | 1.85 | 1.75 |
| 9 | 1.95 | 1.95 | 2.95 | 3.6 | 4.15 | 3.1 | 1.8 | 1.35 | 1.35 | 1.65 | 1.65 | 1.7 |
| 10 | 2.0 | 1.95 | 2.8 | 3.6 | 4.15 | 3.1 | 1.75 | 1.35 | 1.35 | 1.65 | 1.55 | ..... |
| 11 | 2.1 | [a] 3.05 | 2.8 | 3.45 | 4.1 | 3.05 | 1.7 | 1.35 | 1.4 | 1.65 | 1.55 | 2.15 |
| 12 | 2.1 | [a] 3.2 | 2.8 | 3.4 | 4.0 | 3.05 | 1.7 | 1.35 | 1.4 | 1.7 | 1.55 | 2.15 |
| 13 | 2.05 | [a] 2.7 | 2.75 | 3.3 | 3.9 | 3.05 | 1.65 | 1.35 | 1.4 | 1.75 | 1.55 | 1.95 |
| 14 | 2.05 | [a] 2.3 | 2.85 | 3.2 | 3.9 | 3.05 | 1.65 | 1.35 | 1.4 | 1.8 | 1.55 | 1.85 |
| 15 | 2.05 | 1.95 | 3.0 | 3.1 | 3.8 | 3.0 | 1.65 | 1.35 | 1.4 | 1.8 | 1.65 | 1.9 |
| 16 | 2.05 | 1.95 | 3.1 | 3.15 | 3.75 | 2.95 | 1.65 | 1.35 | 1.4 | 1.7 | 1.7 | 1.9 |
| 17 | 2.05 | 2.05 | 3.0 | 3.15 | 3.7 | 2.8 | 1.6 | 1.4 | 1.4 | 1.7 | 1.7 | 1.85 |
| 18 | 2.05 | 1.9 | 2.85 | 3.1 | 3.75 | 2.7 | 1.6 | 1.4 | 1.4 | 1.7 | 1.7 | 1.85 |
| 19 | 2.1 | 1.9 | 3.0 | 3.1 | 3.75 | 2.65 | 1.55 | 1.4 | 1.45 | 1.7 | 1.7 | 1.85 |
| 20 | 2.2 | 1.95 | 3.0 | 3.15 | 3.65 | 2.6 | 1.55 | 1.4 | 1.45 | 1.7 | 1.75 | 1.8 |
| 21 | 2.05 | 2.1 | 3.15 | 3.4 | 3.55 | 2.55 | 1.6 | 1.35 | 1.5 | 1.75 | 1.7 | 1.85 |
| 22 | ..... | 2.2 | 3.2 | 3.4 | 3.5 | 2.45 | 1.55 | 1.35 | 1.5 | 1.75 | 1.6 | 2.0 |
| 23 | 2.45 | 2.3 | 3.25 | ..... | 3.4 | 2.45 | 1.5 | 1.35 | 1.5 | 1.75 | 1.65 | 1.8 |
| 24 | 2.45 | 2.4 | 3.2 | 3.45 | 3.4 | 2.5 | 1.5 | 1.35 | 1.5 | 1.75 | 1.85 | 1.9 |
| 25 | 2.45 | 2.6 | 3.15 | 3.6 | 3.4 | 2.3 | 1.5 | 1.35 | 1.5 | 1.75 | 1.65 | 1.8 |
| 26 | 2.55 | 2.8 | 3.2 | 3.65 | 3.3 | 2.45 | 1.5 | 1.35 | 1.5 | 1.75 | 1.55 | 1.95 |
| 27 | 2.55 | 3.0 | 3.3 | 3.7 | 3.2 | 2.45 | 1.45 | 1.35 | 1.65 | 2.0 | 1.65 | 1.85 |
| 28 | 2.55 | 3.0 | ..... | 3.6 | 3.25 | 2.45 | 1.45 | 1.35 | 1.65 | 2.0 | 1.6 | [a] 2.0 |
| 29 | 2.65 | ..... | 3.35 | 3.6 | 3.2 | 2.45 | 1.4 | 1.3 | 1.7 | 2.0 | 1.95 | [a] 1.95 |
| 30 | 2.45 | ..... | 3.3 | 3.5 | 3.2 | 2.4 | 1.4 | 1.35 | 1.7 | 1.75 | 1.75 | [a] 1.9 |
| 31 | 2.3 | ..... | 3.2 | ..... | 3.2 | ..... | 1.4 | 1.35 | ..... | 1.75 | ..... | [a] 1.9 |

[a] Rise caused by ice gorges; no increased flow.

*Station rating table for Grande Ronde River at Elgin, Oreg., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.30 | 15 | 2.10 | 205 | 2.90 | 590 | 3.70 | 1,310 |
| 1.40 | 27 | 2.20 | 240 | 3.00 | 655 | 3.80 | 1,430 |
| 1.50 | 42 | 2.30 | 280 | 3.10 | 725 | 3.90 | 1,560 |
| 1.60 | 60 | 2.40 | 325 | 3.20 | 805 | 4.00 | 1,700 |
| 1.70 | 82 | 2.50 | 370 | 3.30 | 890 | 4.10 | 1,840 |
| 1.80 | 108 | 2.60 | 420 | 3.40 | 980 | 4.20 | 1,990 |
| 1.90 | 138 | 2.70 | 475 | 3.50 | 1,080 | | |
| 2.00 | 170 | 2.80 | 530 | 3.60 | 1,190 | | |

The above table is applicable only for open-channel conditions. It is based on 11 discharge measurements made during 1904-5. It is well defined between gage heights 1.5 feet and 3.5 feet.

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*Estimated monthly discharge of Grande Ronde River at Elgin, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 448 | 154 | 269 | 16,540 |
| February | 655 | 138 | 244 | 13,550 |
| March | 935 | 502 | 703 | 43,230 |
| April | 1,310 | 725 | 983 | 58,490 |
| May | 1,930 | 805 | 1,308 | 80,430 |
| June | 890 | 280 | 588 | 34,990 |
| July | 280 | 27 | 98.7 | 6,069 |
| August | 27 | 15 | 22.0 | 1,353 |
| September | 82 | 21 | 35.1 | 2,089 |
| October | 170 | 71 | 92.8 | 5,706 |
| November | 123 | 51 | 74.6 | 4,439 |
| December | 222 | 82 | 127 | 7,809 |
| The year | 1,930 | 15 | 379 | 274,700 |

NOTE.—Discharge interpolated for missing gage heights.

## GRANDE RONDE RIVER AT ZINDEL, WASH.

This station was established June 30, 1904, by W. G. Steward. It is located at Zindel Ferry, 2 miles above the mouth of the river and 1½ miles below Joseph Creek.

The channel is curved above the station, but is straight for 1,200 feet below. There are rapids 600 feet above and also 1,200 feet below the station. The right bank is rocky and slopes gradually. It is liable to overflow at extreme high water. The left bank is high, rocky, and not liable to overflow. The bed is rocky and permanent. It is fairly even for soundings. There is one channel at all stages.

Discharge measurements are made from the ferryboat. The distances are measured on the stay line used for the ferry. The initial point is an 8-penny nail in a pine tree 30 feet south of the cable post on the right bank.

An inclined gage is located on the left bank just below the ferry. During 1905 the gage was read once each day by M. W. Zindel, who is paid by the Lewiston Water and Power Company. The bench mark is a point on a rock 29 feet downstream from the gage; elevation, 9.00 feet above the datum of the gage.

A description of this station, with gage heights and discharge data, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 229–230.

*Daily gage height, in feet, of Grande Ronde River at Zindel, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.65 | 2.7 | 3.4 | 4.0 | 4.0 | 4.8 | 3.3 | 2.2 | 2.0 | 2.3 | 2.4 | 2.3 |
| 2 | 2.5 | 2.65 | 3.5 | 3.9 | 4.0 | 5.0 | 3.3 | 2.2 | 2.0 | 2.3 | 2.35 | 2.3 |
| 3 | 2.5 | 2.6 | 3.6 | 3.9 | 4.1 | 4.9 | 3.3 | 2.2 | 2.0 | 2.3 | 2.3 | 2.3 |
| 4 | 2.5 | 2.4 | 3.75 | 3.9 | 4.1 | 5.1 | 3.3 | 2.2 | 2.0 | 2.25 | 2.3 | 2.3 |
| 5 | 2.5 | 2.5 | 3.75 | 4.0 | 4.1 | 5.0 | 3.3 | 2.2 | 2.0 | 2.2 | 2.3 | 2.3 |
| 6 | 2.55 | 2.5 | 3.6 | 4.0 | 4.4 | 4.8 | 3.3 | 2.2 | 2.0 | 2.25 | 2.25 | 2.3 |
| 7 | 2.3 | 2.5 | 3.6 | 4.1 | 4.4 | 4.7 | 3.2 | 2.1 | 2.0 | 2.3 | 2.25 | 2.3 |
| 8 | 2.3 | 2.45 | 3.6 | 4.2 | 4.4 | 4.6 | 3.1 | 2.0 | 2.0 | 2.3 | 2.25 | 2.1 |
| 9 | 2.25 | 2.4 | 3.6 | 4.2 | 4.5 | 5.1 | 3.0 | 2.0 | 2.0 | 2.3 | 2.2 | 2.1 |
| 10 | 2.25 | 2.3 | 3.5 | 4.2 | 4.6 | 4.5 | 3.0 | 2.0 | 2.0 | 2.3 | 2.2 | 2.0 |
| 11 | 2.2 | 2.3 | 3.4 | 4.0 | 4.8 | 4.8 | 3.0 | 2.0 | 1.95 | 2.3 | 2.2 | 2.0 |
| 12 | 2.2 | 2.25 | 3.3 | 3.9 | 4.8 | 4.8 | 2.9 | 2.0 | 1.95 | 2.3 | 2.2 | 2.25 |
| 13 | 2.2 | 2.2 | 3.4 | 3.8 | 4.7 | 4.0 | 2.7 | 2.0 | 2.0 | 2.35 | 2.2 | 2.25 |

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*Daily gage height, in feet, of Grande Ronde River at Zindel, Wash., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 2.25 | 2.2 | 3.4 | 3.7 | 4.5 | 4.0 | 2.7 | 2.0 | 2.0 | 2.35 | 2.2 | 2.25 |
| 15 | 2.25 | 2.2 | 3.4 | 3.7 | 4.3 | 3.9 | 2.6 | 2.0 | 2.0 | 2.35 | 2.2 | 2.3 |
| 16 | 2.25 | 2.2 | 3.5 | 3.7 | 4.2 | 3.9 | 2.5 | 2.0 | 2.0 | 2.35 | 2.2 | 2.3 |
| 17 | 2.3 | 2.25 | 3.7 | 3.7 | 4.55 | 3.8 | 2.5 | 2.0 | 2.0 | 2.35 | 2.25 | 2.3 |
| 18 | 2.3 | 2.3 | 3.8 | 3.8 | 4.5 | 3.8 | 2.5 | 2.0 | 2.0 | 2.3 | 2.25 | 2.3 |
| 19 | 2.4 | 2.3 | 3.7 | 3.9 | 4.4 | 3.8 | 2.5 | 2.0 | 2.0 | 2.3 | 2.25 | 2.3 |
| 20 | 2.4 | 2.4 | 3.8 | 4.1 | 4.4 | 3.8 | 2.5 | 2.0 | 2.0 | 2.3 | 2.25 | 2.3 |
| 21 | 2.4 | 2.95 | 3.8 | 4.1 | 4.4 | 3.7 | 2.3 | 2.0 | 2.0 | 2.3 | 2.2 | 2.3 |
| 22 | 2.4 | 2.9 | 3.8 | 4.1 | 4.2 | 3.7 | 2.3 | 2.0 | 2.0 | 2.3 | 2.2 | 2.25 |
| 23 | 2.4 | 2.9 | 3.9 | 4.2 | 4.2 | 3.7 | 2.3 | 2.0 | 2.0 | 2.3 | 2.2 | 2.1 |
| 24 | 2.8 | 3.1 | 3.9 | 4.3 | 4.1 | 3.9 | 2.3 | 2.0 | 2.0 | 2.3 | 2.2 | 2.1 |
| 25 | 3.2 | 3.2 | 4.1 | 4.3 | 4.0 | 3.8 | 2.3 | 2.0 | 2.0 | 2.3 | 2.25 | 2.25 |
| 26 | 3.1 | 3.35 | 4.1 | 4.5 | 3.9 | 3.8 | 2.2 | 2.0 | 2.0 | 2.4 | 2.3 | 2.3 |
| 27 | 3.2 | 3.5 | 4.3 | 4.6 | 4.0 | 3.6 | 2.2 | 2.0 | 2.1 | 2.5 | 2.6 | 2.3 |
| 28 | 3.1 | 3.4 | 4.2 | 4.6 | 4.1 | 3.6 | 2.2 | 2.0 | 2.1 | 2.4 | 2.6 | 2.3 |
| 29 | 3.1 | ..... | 4.2 | 4.2 | 4.2 | 3.4 | 2.2 | 2.0 | 2.3 | 2.4 | 2.4 | 2.25 |
| 30 | 3.0 | ..... | 4.3 | 4.1 | 4.3 | 3.4 | 2.2 | 2.0 | 2.3 | 2.4 | 2.3 | 2.25 |
| 31 | 2.8 | ..... | 4.3 | ..... | 4.4 | ..... | 2.2 | 2.0 | ..... | 2.4 | ..... | 2.25 |

## WALLOWA LAKE NEAR JOSEPH, OREG.

July 15, 1905, a gage was placed on the upstream side of the controlling dam at the outlet of Wallowa Lake and was read twice each week during the remainder of the year. It is fastened to the crib pier nearest the right bank. Its datum is the floor of the sluiceway

*Daily gage height, in feet, of Wallowa Lake near Joseph, Oreg., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | ..... | ..... | ..... | 0.65 | ..... | 16 | ..... | 1.0 | 0.75 | ..... | ..... | 0.6 |
| 2 | ..... | 2.1 | 0.85 | ..... | ..... | 0.6 | 18 | ..... | ..... | ..... | 0.7 | 0.6 | ..... |
| 4 | ..... | ..... | ..... | 0.8 | .65 | ..... | 19 | 4.2 | 1.0 | .65 | ..... | ..... | ..... |
| 5 | ..... | 1.6 | ..... | ..... | ..... | ..... | 21 | ..... | ..... | ..... | .7 | ..... | ..... |
| 6 | ..... | ..... | .8 | ..... | .65 | .6 | 22 | 3.7 | ..... | ..... | ..... | .6 | ..... |
| 7 | ..... | ..... | ..... | .8 | ..... | ..... | 23 | ..... | .9 | .7 | ..... | ..... | .6 |
| 9 | ..... | ..... | .75 | ..... | ..... | .6 | 25 | ..... | ..... | ..... | .7 | .6 | ..... |
| 10 | ..... | 1.3 | ..... | ..... | ..... | ..... | 26 | 3.6 | ..... | ..... | ..... | ..... | ..... |
| 11 | ..... | ..... | ..... | ..... | .6 | ..... | 27 | ..... | ..... | .75 | ..... | ..... | .6 |
| 12 | ..... | 1.1 | ..... | ..... | ..... | ..... | 28 | ..... | ..... | ..... | .65 | ..... | ..... |
| 13 | ..... | ..... | .8 | ..... | ..... | .6 | 29 | 3.1 | ..... | ..... | ..... | .6 | ..... |
| 15 | 4.5 | ..... | ..... | ..... | ..... | ..... | 30 | ..... | .9 | .85 | ..... | ..... | ..... |

## WALLOWA RIVER NEAR JOSEPH, OREG.

This station was established November 12, 1903, by John H. Lewis. It is located 500 feet below the outlet of Wallowa Lake, about 1¼ miles above Joseph, Oreg.

The channel is straight for 100 feet above and 75 feet below the station. The right bank is liable to overflow at high water for about 30 feet, at which point it becomes steep. The left bank will overflow for about 20 feet at high water. Both banks are timbered. At the bridge the bed of the stream is composed of large bowlders, is free from vegetation, and is not liable to shift. There is but one channel at all stages.

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Discharge measurements are made from a footbridge, which has a single span of 50 feet. The initial point for soundings is the end of the upstream log supporting the footbridge on the left bank.

The original gage was a vertical staff located on Wallowa Lake near the outlet. On account of the construction of a controlling dam at the outlet, this gage was rendered useless. From March 30 to July 12, 1905, readings were taken on a temporary gage about 100 feet below the dam. July 12, 1905, a permanent vertical rod gage was established on the right bank of the river, about 50 feet above the footbridge. The readings on the temporary gage have been reduced to correspond with those on the permanent one. During 1905 the gage was read once each day by F. L. Bedingfield. The new gage is referred to the following bench mark: A cross cut in the highest point of the rock to which the gage is attached; elevation, 4.10 feet above the datum of the gage.

Four irrigation ditches divert a considerable portion of the water between the station and the town of Joseph, and gages have been read on them twice weekly since July 12.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 418; 135, pp 230–231.
Discharge: 100, p 418; 135, p 231.
Discharge, monthly: 135, p 232.
Gage heights: 100, p 418; 135, p 231.
Rating table: 135, p 232.

*Discharge measurements of Wallowa River near Joseph, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| March 30 | W. C. Sawyer | 27 | 34.5 | 2.37 | 1.51 | 82 |
| May 18 | do | 27 | 42.0 | 2.43 | 2.20 | 102 |
| July 10 | do | 28 | 50.0 | 4.08 | 2.43 | 202 |
| July 11 | do | 27 | 36.1 | 3.62 | 2.30 | 131 |
| July 11 | do | 28 | 52.0 | 4.63 | 2.58 | 239 |
| July 11 | do | 27 | 29.5 | 2.82 | 2.17 | 83 |
| July 12 | do | 30 | 61.0 | 5.20 | 2.74 | 319 |
| September 19 | do | 27 | 25.5 | 2.31 | 2.05 | 59 |
| November 27 | R. S. Hall | 28 | 32.4 | 2.33 | 2.02 | 76 |

*Daily gage height, in feet, of Wallowa River near Joseph, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.4 | 1.2 | 1.2 | 2.0 | 2.15 | 2.95 | 2.7 | 2.8 | 2.15 | 2.1 | 2.0 | 1.9 |
| 2 | 1.4 | 1.2 | 1.2 | 2.0 | 2.15 | 3.15 | 2.6 | 2.8 | ..... | 2.1 | 2.0 | 1.9 |
| 3 | 1.4 | 1.2 | 1.2 | 2.0 | 2.15 | 3.2 | 2.6 | 2.7 | 2.1 | 2.1 | 2.0 | 1.9 |
| 4 | 1.4 | 1.2 | 1.2 | 2.0 | 2.15 | 3.2 | 2.6 | 2.7 | 2.1 | 2.1 | 2.0 | 1.9 |
| 5 | 1.3 | 1.2 | 1.2 | 2.0 | ..... | 3.3 | 2.6 | 2.6 | 2.1 | 2.1 | 2.0 | 1.9 |
| 6 | 1.3 | 1.2 | 1.2 | 2.0 | 2.15 | 3.35 | 2.7 | 2.55 | 2.1 | 2.15 | 2.0 | 1.9 |
| 7 | 1.3 | 1.2 | 1.2 | 2.0 | 2.15 | 3.3 | 2.75 | 2.5 | 2.1 | 2.2 | 2.0 | ..... |
| 8 | 1.3 | 1.2 | 1.2 | 2.0 | 2.15 | 3.2 | 2.75 | 2.5 | 2.1 | 2.2 | 2.0 | 1.9 |
| 9 | 1.3 | 1.1 | 1.2 | 2.0 | 2.15 | 3.05 | 2.6 | 2.5 | 2.1 | 2.2 | 2.0 | 1.9 |
| 10 | ..... | 1.1 | 1.2 | 2.05 | 2.05 | 3.05 | 2.6 | 2.4 | 2.1 | 2.1 | 2.0 | 1.9 |
| 11 | 1.3 | 1.2 | 1.2 | 2.05 | 2.05 | 3.15 | 2.6 | 2.4 | 2.1 | 2.1 | 2.0 | 1.9 |
| 12 | 1.3 | 1.2 | 1.2 | 2.0 | 2.05 | 3.05 | 2.5 | 2.4 | 2.1 | 2.1 | 2.0 | 1.9 |
| 13 | 1.3 | 1.2 | ..... | 2.0 | 2.05 | 3.15 | 2.8 | 2.4 | 2.1 | 2.1 | 2.0 | 1.9 |
| 14 | 1.3 | 1.2 | ..... | ..... | 2.05 | 3.15 | 2.8 | 2.4 | 2.1 | 2.1 | 2.0 | 1.9 |

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*Daily gage height, in feet, of Wallowa River near Joseph, Oreg., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 1.3 | 1.2 | 1.2 | 2.0 | 2.0 | 3.05 | 2.7 | 2.35 | 2.1 | 2.1 | 2.0 | 1.9 |
| 16 | 1.3 | 1.2 | 1.3 | 2.0 | 2.0 | 3.05 | 2.7 | 2.3 | 2.05 | 2.1 | 2.0 | 1.9 |
| 17 | 1.3 | 1.2 | 1.3 | 2.05 | 2.0 | 3.05 | 2.6 | 2.3 | 2.0 | 2.1 | 2.0 | 1.9 |
| 18 | 1.3 | 1.2 | 1.3 | 2.05 | 2.0 | 3.05 | 2.6 | 2.3 | 2.05 | 2.1 | 2.0 | 1.9 |
| 19 | 1.3 | 1.2 | 1.3 | 2.05 | 2.2 | 2.95 | 2.6 | 2.3 | 2.0 | 2.1 | 2.0 | 1.9 |
| 20 | 1.2 | ..... | 1.4 | 2.05 | 2.15 | 2.85 | 2.7 | 2.25 | 2.0 | 2.1 | 2.0 | 1.9 |
| 21 | 1.2 | 1.3 | ..... | 2.1 | 2.1 | 2.9 | 2.8 | 2.25 | 2.0 | 2.1 | 2.0 | 1.9 |
| 22 | 1.3 | 1.2 | ..... | 2.1 | 2.1 | 2.9 | 2.8 | 2.3 | 2.0 | 2.05 | 1.95 | 1.9 |
| 23 | 1.3 | 1.2 | ..... | 2.1 | 2.15 | 2.9 | 2.8 | 2.25 | 2.0 | 2.05 | 1.95 | 1.9 |
| 24 | ..... | 1.2 | 1.4 | 2.1 | 2.25 | 2.85 | 2.7 | 2.25 | ..... | 2.05 | 1.9 | 1.9 |
| 25 | ..... | 1.2 | ..... | 2.1 | 2.3 | 2.8 | 2.8 | 2.25 | 2.0 | 2.05 | 1.9 | 1.9 |
| 26 | 1.3 | 1.2 | 1.4 | 2.1 | 2.2 | 2.8 | 2.6 | 2.25 | 2.0 | 2.05 | 1.9 | 1.9 |
| 27 | 1.3 | 1.2 | 1.4 | 2.1 | 2.2 | 2.75 | 2.7 | 2.2 | 2.0 | 2.05 | 1.95 | 1.9 |
| 28 | 1.3 | 1.2 | ..... | 2.1 | 2.1 | 2.6 | 2.7 | 2.2 | 2.05 | 2.0 | 1.95 | 1.9 |
| 29 | 1.3 | ..... | 1.5 | 2.15 | 2.15 | 2.6 | 2.7 | 2.2 | 2.2 | 2.0 | 1.95 | 1.9 |
| 30 | ..... | ..... | 1.6 | 2.15 | 2.15 | 2.6 | ..... | 2.2 | 2.2 | 2.0 | 1.95 | 1.95 |
| 31 | 1.3 | ..... | 2.0 | ..... | 2.9 | ..... | 2.8 | 2.2 | ..... | 2.0 | ..... | 1.9 |

NOTE.—Gage heights, January 1 to March 30, refer to lake-gage datum. During the remainder of the year gage heights refer to new gage.

*Station rating table for Wallowa River near Joseph, Oreg., from November 13, 1903, to March 30, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet* | *Second-feet.* |
| 1.20 | 53 | 2.00 | 157 | 2.80 | 344 | 3.60 | 609 |
| 1.30 | 63 | 2.10 | 175 | 2.90 | 374 | 3.70 | 643 |
| 1.40 | 73 | 2.20 | 195 | 3.00 | 406 | 3.80 | 677 |
| 1.50 | 85 | 2.30 | 216 | 3.10 | 439 | 3.90 | 711 |
| 1.60 | 97 | 2.40 | 238 | 3.20 | 473 | 4.00 | 745 |
| 1.70 | 110 | 2.50 | 262 | 3.30 | 507 | | |
| 1.80 | 125 | 2.60 | 288 | 3.40 | 541 | | |
| 1.90 | 141 | 2.70 | 315 | 3.50 | 575 | | |

The above table is applicable only for open-channel conditions. It is based on six discharge measurements made during 1903–4. It is well defined between gage heights 1.5 feet and 3 feet.

*Station rating table for Wallowa River near Joseph, Oreg., from March 31 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.90 | 35 | 2.30 | 135 | 2.70 | 299 | 3.10 | 527 |
| 2.00 | 54 | 2.40 | 170 | 2.80 | 350 | 3.20 | 597 |
| 2.10 | 77 | 2.50 | 209 | 2.90 | 405 | 3.30 | 675 |
| 2.20 | 104 | 2.60 | 252 | 3.00 | 464 | | |

The above table is applicable only for open-channel conditions. It is based on eight discharge measurements made during 1905. It is well defined between gage heights 2 feet and 2.8 feet.

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*Estimated monthly discharge of Wallowa River near Joseph, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 73 | 53 | 63.6 | 3,911 |
| February | 63 | 45 | 53.0 | 2,943 |
| March | 97 | 53 | 62.6 | 3,849 |
| April | 90 | 54 | 64.7 | 3,850 |
| May | 405 | 54 | 94.0 | 5,780 |
| June | 717 | 252 | 473 | 28,140 |
| July | 350 | 209 | 293 | 18,020 |
| August | 350 | 104 | 172 | 10,580 |
| September | 104 | 54 | 70.8 | 4,213 |
| October | 104 | 54 | 74.7 | 4,593 |
| November | 54 | 35 | 50.1 | 2,981 |
| December | 44 | 35 | 35.3 | 2,170 |
| The year | 717 | 35 | 126 | 91,030 |

## WALLOWA RIVER NEAR WALLOWA, OREG.

This station was established November 14, 1903, by John H. Lewis. It is located at the county bridge, 1½ miles below Wallowa, Oreg., and one-fourth mile below the mouth of Bear Creek. A small irrigation ditch takes water from the river about 300 feet above the bridge on the right bank.

The channel is straight for 400 feet above and 600 feet below the station. The current is swift. Both banks are low, wooded, and not liable to overflow. The bed of the stream is composed of gravel, is free from vegetation, and is not liable to shift. There is but one channel at low water. At high water the channel is broken by the rock-filled timber crib pier, to which the gage is fastened.

Discharge measurements are made from the upstream side of the bridge to which the gage is attached. The initial point for soundings is the left end of the lower chord on the upstream side of the bridge.

A staff gage is fastened vertically to the downstream side of the timber crib pier on the right bank. During 1905 the gage was read once each day by L. S. Johnson. Bench marks were established as follows: (1) The head of a 30-penny wire nail driven nearly flush with the top of the crib, 2 inches from the edge, near the gage; elevation, 6.60 feet. (2) A square chisel draft on top of a rock near the rail fence across the ditch 50 feet from the right end of the bridge; elevation, 8.10 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 417; 135, pp 232–233.
Discharge: 100, p 417; 135, p 233.
Discharge, monthly: 135, p 234.
Gage heights: 100, p 417; 135, pp 233–234.
Rating table: 135, p 234.

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*Discharge measurements of Wallowa River near Wallowa, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| March 31 | W. C. Sawyer | 81.5 | 93 | 3.45 | 1.93 | 322 |
| May 19 | do | 88.0 | 173 | 4.71 | 2.86 | 815 |
| July 8 | do | 86.0 | 142 | 4.32 | 2.56 | 614 |
| September 18 | do | 84.0 | 80 | 2.49 | 1.72 | 199 |
| November 29 | R. S. Hall | 82.0 | 98 | 2.65 | 1.90 | 261 |

*Daily gage height, in feet, of Wallowa River near Wallowa, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.0 | 1.7 | 1.9 | 2.0 | 2.4 | 3.9 | 2.8 | 1.9 | 1.7 | 2.0 | 2.0 | 1.85 |
| 2 | 1.9 | 1.8 | 1.9 | 2.0 | 2.4 | 3.9 | 2.8 | 1.9 | 1.7 | 1.9 | 2.0 | 1.85 |
| 3 | 1.9 | 1.8 | 2.0 | 2.0 | 2.5 | 4.0 | 2.8 | 1.9 | 1.7 | 1.9 | 2.0 | 1.85 |
| 4 | 1.8 | 1.8 | 2.0 | 2.0 | 2.5 | 4.0 | 2.8 | 1.9 | 1.7 | 1.9 | 1.95 | 1.9 |
| 5 | 1.7 | 1.8 | 2.0 | 2.0 | 2.5 | 3.8 | 2.8 | 1.9 | 1.7 | 1.85 | 1.95 | 1.9 |
| 6 | 1.8 | 1.8 | 2.0 | 2.1 | 2.5 | 3.7 | 2.8 | 1.8 | 1.7 | 1.85 | 1.95 | 1.9 |
| 7 | 1.8 | 1.8 | 2.0 | 2.1 | 2.6 | 3.6 | 2.8 | 1.8 | 1.7 | 2.0 | 1.95 | 1.9 |
| 8 | 1.8 | 1.8 | 2.0 | 2.3 | 2.7 | 3.7 | 2.5 | 1.8 | 1.7 | 2.0 | 1.95 | 1.9 |
| 9 | 1.8 | 1.7 | 2.0 | 2.3 | 2.8 | 4.2 | 2.5 | 1.7 | 1.7 | 2.0 | 1.95 | 1.75 |
| 10 | 1.8 | 1.7 | 2.0 | 2.3 | 2.2 | 4.0 | 2.5 | 1.7 | 1.7 | 2.0 | 1.95 | 1.7 |
| 11 | 1.7 | 1.5 | 2.0 | 2.2 | 2.6 | 4.0 | 2.3 | 1.7 | 1.7 | 2.0 | 1.9 | 1.7 |
| 12 | 1.8 | 1.5 | 2.0 | 2.2 | 2.5 | 4.0 | 2.3 | 1.7 | 1.7 | 2.0 | 1.9 | 2.0 |
| 13 | 2.2 | 2.0 | 2.0 | 2.2 | 2.5 | 3.9 | 2.3 | 1.7 | 1.7 | 2.0 | 1.9 | 2.4 |
| 14 | 1.8 | 2.3 | 2.1 | 2.1 | 2.5 | 3.8 | 2.3 | 1.7 | 1.7 | 2.0 | 1.9 | 2.4 |
| 15 | 1.8 | 2.3 | 2.1 | 2.1 | 2.4 | 3.6 | 2.2 | 1.6 | 1.7 | 2.05 | 1.9 | 2.4 |
| 16 | 1.8 | 2.5 | 2.1 | 2.1 | 2.5 | 3.9 | 2.2 | 1.6 | 1.8 | 2.1 | 1.85 | 2.0 |
| 17 | 1.8 | 2.5 | 2.1 | 2.1 | 3.0 | 3.7 | 2.2 | 1.7 | 1.8 | 2.0 | 1.85 | 1.8 |
| 18 | 1.8 | 2.5 | 2.1 | 2.0 | 2.9 | 3.0 | 2.0 | 1.7 | 1.8 | 2.0 | 1.95 | 1.8 |
| 19 | 1.8 | 1.7 | 2.1 | 2.1 | 2.9 | 3.0 | 2.0 | 1.7 | 1.7 | 2.0 | 1 95 | 1.8 |
| 20 | 1.8 | 1.9 | 2.1 | 2.1 | 3.0 | 3.1 | 2.0 | 1.7 | 1.7 | 2.0 | 1.95 | 1.8 |
| 21 | 1.8 | 2.0 | 2.1 | 2.2 | 2.8 | 3.1 | 1.9 | 1.7 | 1.7 | 2.0 | 1.9 | 1.8 |
| 22 | 1.8 | 2.0 | 2.1 | 2.2 | 2.7 | 3.1 | 1.8 | 1.7 | 1.7 | 2.0 | 1.85 | 1.8 |
| 23 | 1.8 | 2.0 | 2.0 | 2.3 | 2.6 | 3.1 | 1.8 | 1.7 | 1.7 | 2.0 | 1.8 | 1.8 |
| 24 | 1.9 | 2.0 | 2.0 | 2.4 | 2.5 | 3.2 | 1.8 | 1.7 | 1.7 | 2.0 | 1.8 | 1.8 |
| 25 | 2.3 | 2.0 | 2.0 | 2.5 | 2.5 | 3.1 | 1.8 | 1.7 | 1.7 | 2.05 | 1.85 | 1.85 |
| 26 | 2.0 | 2.0 | 2.1 | 2.8 | 2.6 | 3.0 | 1.9 | 1.7 | 1.7 | 2.1 | 2.0 | 1.8 |
| 27 | 2.0 | 2.0 | 2.1 | 2.7 | 2.9 | 2.9 | 1.9 | 1.7 | 1.9 | 2.05 | 2.0 | 1.8 |
| 28 | 2.0 | 2.0 | 2.0 | 2.5 | 3.0 | 2.8 | 1.8 | 1.7 | 2.05 | 2.05 | 1.9 | 1.8 |
| 29 | 1.9 | ..... | 2.0 | 2.4 | 3.0 | 2.7 | 1.9 | 1.7 | 2.0 | 2.05 | 1.9 | 1.8 |
| 30 | 1.9 | ..... | 2.0 | 2.5 | 3.2 | 2.9 | 1.9 | 1.7 | 2.0 | 2.0 | 1.9 | 1.8 |
| 31 | 1.8 | ..... | 2.0 | ..... | 3.5 | ..... | 1.9 | 1.7 | ..... | 2.0 | ..... | 1.8 |

NOTE.—Anchor ice during part of January, February, and December.

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*Station rating table for Wallowa River near Wallowa, Oreg., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.50 | 140 | 2.20 | 412 | 2.90 | 862 | 3.60 | 1,616 |
| 1.60 | 168 | 2.30 | 462 | 3.00 | 960 | 3.70 | 1,730 |
| 1.70 | 200 | 2.40 | 514 | 3.10 | 1,063 | 3.80 | 1,844 |
| 1.80 | 236 | 2.50 | 568 | 3.20 | 1,169 | 3.90 | 1,958 |
| 1.90 | 276 | 2.60 | 626 | 3.30 | 1,277 | 4.00 | 2,072 |
| 2.00 | 318 | 2.70 | 693 | 3.40 | 1,388 | 4.10 | 2,186 |
| 2.10 | 364 | 2.80 | 772 | 3.50 | 1,502 | 4.20 | 2,300 |

The above table is applicable only for open-channel conditions. It is based on nine discharge measurements made during 1903–1905. It is fairly well defined between gage heights 1.7 feet and 3.1 feet.
The table has been extended beyond these limits.
Above gage height 2.6 feet the table is the same as that of 1904.

*Estimated monthly discharge of Wallowa River near Wallowa, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 462 | 200 | 264 | 16,230 |
| February | 318 | 140 | 228 | 12,660 |
| March | 364 | 276 | 332 | 20,410 |
| April | 772 | 318 | 431 | 25,650 |
| May | 1,502 | 412 | 715 | 43,960 |
| June | 2,300 | 693 | 1,505 | 89,550 |
| July | 772 | 236 | 451 | 27,730 |
| August | 276 | 168 | 214 | 13,160 |
| September | 341 | 200 | 219 | 13,030 |
| October | 364 | 256 | 317 | 19,490 |
| November | 318 | 236 | 285 | 16,960 |
| December | 514 | 200 | 274 | 16,850 |
| The year | 2,300 | 140 | 436 | 315,700 |

## WALLOWA RIVER NEAR ELGIN, OREG.

This station was established November 18, 1903, by John H. Lewis. It is located at the county highway bridge just below the mouth of Minam River, 12 miles from Elgin, Oreg. The station is in Wallowa Canyon about 9 miles below the lower end of Wallowa Valley.

The channel is straight for 100 feet above and 1,000 feet below the station. Both banks are high, rocky, not liable to overflow, and without timber or brush. The current is swift. The bed of the stream is composed of gravel, and is free from vegetation and not liable to shift. There is but one channel at all stages.

Discharge measurements are made from the downstream side of the single-span bridge to which the gage is attached. On account of the velocity of the water a stay wire is used in making discharge measurements. The initial point for soundings is the end of the bridge rail on the left bank.

The gage is in two sections, located under the lower side of the bridge on the left bank. The lower or inclined section reads from 1.7 to 3 feet. The upper or vertical section reads from 3 to 10 feet. During 1905 the gage was read once each day by Samuel Spores and G. W. Weir. Bench marks were established as follows: (1) The highest point of the rock to which the vertical section of the gage is fastened, 6 inches from the gage rod; elevation, 9.60 feet. (2) The center of the hole in the rock in which the bolt supporting vertical rod is set; elevation, 7.07 feet. Elevations refer to the datum of the gage.

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Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 416–417; 135, p 235.
Discharge: 100, p 417; 135, p 235.
Discharge, monthly: 135, p 237.
Gage heights: 100, p 417; 135, p 236.
Rating table: 135, p 236.

*Discharge measurements of Wallowa River near Elgin, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| April 1 | W. C. Sawyer | 140 | 218 | 3.66 | 2.85 | 800 |
| May 20 | do | 161 | 383 | 4.84 | 3.86 | 1,854 |
| July 7 | do | 160 | 296 | 3.74 | 3.27 | 1,107 |
| September 16 | do | 145 | 138 | 2.16 | 2.18 | 298 |
| November 30 [a] | R. S. Hall | 172 | 209 | 1.70 | 2.34 | 358 |

[a] Made at different section.

*Daily gage height, in feet, of Wallowa River near Elgin, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.5 | 2.4 | 2.7 | 2.9 | 3.2 | 4.9 | 3.3 | 2.4 | 2.0 | 2.45 | 2.5 | 2.3 |
| 2 | 2.5 | 2.4 | 2.7 | 2.9 | 3.2 | 5.0 | 3.5 | 2.4 | 2.0 | 2.4 | 2.6 | 2.3 |
| 3 | 2.5 | 2.4 | 2.8 | 2.9 | 3.3 | 5.0 | 3.5 | 2.4 | 2.0 | 2.4 | 2.6 | 2.3 |
| 4 | 2.3 | 2.4 | 2.8 | 2.9 | 3.3 | 4.9 | 3.5 | 2.4 | 2.0 | 2.35 | 2.6 | 2.3 |
| 5 | 2.3 | 2.3 | 2.8 | 3.0 | 3.5 | 4.7 | 3.5 | 2.4 | 2.0 | 2.35 | 2.55 | 2.3 |
| 6 | 2.3 | 2.3 | 2.8 | 3.0 | 3.5 | 4.4 | 3.4 | 2.3 | 2.0 | 2.35 | 2.5 | 2.3 |
| 7 | 2.3 | 2.3 | 2.8 | 3.1 | 3.6 | 4.4 | 3.4 | 2.3 | 2.0 | 2.6 | 2.5 | 2.3 |
| 8 | 2.2 | 2.2 | 2.7 | 3.1 | 3.7 | 4.6 | 3.3 | 2.3 | 2.0 | 2.55 | 2.5 | 2.3 |
| 9 | 2.2 | 2.1 | 2.7 | 3.1 | 3.7 | 5.0 | 3.2 | 2.3 | 2.0 | 2.55 | 2.5 | 2.3 |
| 10 | 2.1 | 2.0 | 2.7 | 3.1 | 3.6 | 4.9 | 3.2 | 2.3 | 2.0 | 2.5 | 2.5 | 2.05 |
| 11 | 2.1 | 2.0 | 2.7 | 3.0 | 3.5 | 4.9 | 3.1 | 2.3 | 2.0 | 2.55 | 2.45 | 2.05 |
| 12 | 2.2 | 2.0 | 2.7 | 3.0 | 3.4 | 4.8 | 2.9 | 2.3 | 2.0 | 2.6 | 2.45 | 2.1 |
| 13 | 2.3 | 2.0 | 2.7 | 3.0 | 3.3 | 4.6 | 2.8 | 2.2 | 2.0 | 2.6 | 2.45 | 2.1 |
| 14 | 2.3 | 2.2 | 2.9 | 2.9 | 3.3 | 4.4 | 2.6 | 2.1 | 2.0 | 2.6 | 2.4 | 2.1 |
| 15 | 2.4 | 2.2 | 2.9 | 2.9 | 3.3 | 4.2 | 2.7 | 2.1 | 2.0 | 2.7 | 2.4 | 2.15 |
| 16 | 2.4 | 2.3 | 2.9 | 2.9 | 3.4 | 3.6 | 2.6 | 2.1 | 2.0 | 2.65 | 2.4 | 2.15 |
| 17 | 2.4 | 2.4 | 2.8 | 2.9 | 3.9 | 3.5 | 2.6 | 2.1 | 2.2 | 2.7 | 2.4 | 2.2 |
| 18 | 2.4 | 2.6 | 2.8 | 2.8 | 3.8 | 3.8 | 2.5 | 2.1 | 2.2 | 2.6 | 2.4 | 2.2 |
| 19 | 2.4 | 2.5 | 2.8 | 2.8 | 3.8 | 3.8 | 2.5 | 2.1 | 2.2 | 2.6 | 2.45 | 2.2 |
| 20 | 2.3 | 2.5 | 2.8 | 2.9 | 4.0 | 3.9 | 2.5 | 2.0 | 2.2 | 2.6 | 2.5 | 2.3 |
| 21 | 2.3 | 2.5 | 2.8 | 2.9 | 3.7 | 4.0 | 2.5 | 2.0 | 2.2 | 2.6 | 2.5 | 2.4 |
| 22 | 2.3 | 2.5 | 2.8 | 3.0 | 3.6 | 4.1 | 2.5 | 2.0 | 2.2 | 2.55 | 2.5 | 2.3 |
| 23 | 2.3 | 2.5 | 2.8 | 3.2 | 3.5 | 3.9 | 2.5 | 2.0 | 2.2 | 2.6 | 2.35 | 2.35 |
| 24 | 2.4 | 2.6 | 2.8 | 3.3 | 3.4 | 4.0 | 2.5 | 2.0 | 2.2 | 2.65 | 2.35 | 2.3 |
| 25 | 2.8 | 2.7 | 2.8 | 3.4 | 3.3 | 3.8 | 2.5 | 2.0 | 2.2 | 2.65 | 2.4 | 2.4 |
| 26 | 2.6 | 2.7 | 2.8 | 3.7 | 3.4 | 3.7 | 2.5 | 2.0 | 2.2 | 2.8 | 2.4 | 2.5 |
| 27 | 2.6 | 2.7 | 2.9 | 3.5 | 3.8 | 3.6 | 2.5 | 2.0 | 2.25 | 2.7 | 2.35 | 2.6 |
| 28 | 2.6 | 2.7 | 2.9 | 3.3 | 3.8 | 3.5 | 2.5 | 2.0 | 2.5 | 2.6 | 2.3 | 2.4 |
| 29 | 2.5 | ..... | 2.9 | 3.2 | 3.9 | 3.4 | 2.4 | 2.0 | 2.6 | 2.6 | 2.3 | 2.4 |
| 30 | 2.4 | ..... | 2.9 | 3.3 | 4.2 | 3.3 | 2.4 | 2.0 | 2.45 | 2.6 | 2.3 | 2.4 |
| 31 | 2.4 | ..... | 2.9 | ..... | 4.9 | ..... | 2.4 | 2.0 | ..... | 2.55 | ..... | 2.35 |

NOTE.—No ice record.

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*Station rating table for Wallowa River near Elgin, Oreg., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.00 | 215 | 2.80 | 680 | 3.60 | 1,550 | 4.40 | 2,670 |
| 2.10 | 255 | 2.90 | 770 | 3.70 | 1,680 | 4.50 | 2,830 |
| 2.20 | 300 | 3.00 | 870 | 3.80 | 1,810 | 4.60 | 2,990 |
| 2.30 | 350 | 3.10 | 970 | 3.90 | 1,940 | 4.70 | 3,150 |
| 2.40 | 405 | 3.20 | 1,080 | 4.00 | 2,080 | 4.80 | 3,310 |
| 2.50 | 465 | 3.30 | 1,190 | 4.10 | 2,220 | 4.90 | 3,480 |
| 2.60 | 530 | 3.40 | 1,310 | 4.20 | 2,370 | 5.00 | 3,650 |
| 2.70 | 600 | 3.50 | 1,430 | 4.30 | 2,520 | | |

The above table is applicable only for open-channel conditions. It is based on eight discharge measurements made during 1903–1905. It is well defined between gage heights 2.2 feet and 4 feet.

*Estimated monthly discharge of Wallowa River near Elgin, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 680 | 255 | 396 | 24,350 |
| February | 600 | 215 | 401 | 22,270 |
| March | 770 | 600 | 683 | 42,000 |
| April | 1,680 | 680 | 944 | 56,170 |
| May | 3,480 | 1,080 | 1,581 | 97,210 |
| June | 3,650 | 1,190 | 2,451 | 145,800 |
| July | 1,430 | 405 | 768 | 47,220 |
| August | 405 | 215 | 287 | 17,650 |
| September | 530 | 215 | 273 | 16,240 |
| October | 680 | 378 | 512 | 31,480 |
| November | 530 | 350 | 434 | 25,820 |
| December | 725 | 235 | 355 | 21,830 |
| The year | 3,650 | 215 | 740 | 548,000 |

## DITCHES IN WALLOWA RIVER VALLEY, OREGON.

### SILVER LAKE DITCH NEAR JOSEPH, OREG.

This ditch diverts water from the right bank of Wallowa River about 1 mile above Joseph and one-eighth mile below the outlet of Wallowa Lake. Its head is 75 feet below the river gaging station.

The gage is a vertical rod on the left bank one-fourth mile below the bend, and is read twice a week by F. L. Bedingfield.

*Discharge measurements of Silver Lake ditch near Joseph, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet* | *Feet per second* | *Feet* | *Second-feet* |
| July 12 | W. C. Sawyer | 12 | 20.5 | 3.61 | 1.30 | 74.1 |
| September 19 | do | 11 | 10.4 | 1.55 | .43 | 16.1 |
| November 27 | do | 10 | 6.2 | .47 | .10 | 2.9 |

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*Daily gage height, in feet, of Silver Lake ditch near Joseph, Oreg., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | 0.45 | | 16 | | 1.0 | 0.45 | | | 0.05 |
| 2 | | (a) | 0.5 | | | 0.05 | 18 | | | | 0.5 | 0.1 | |
| 4 | | | | 0.3 | .2 | | 19 | 1.3 | 1.0 | | | | |
| 5 | | 1.2 | | | | | 20 | | | .35 | | | |
| 6 | | | .45 | | | .05 | 21 | | | | .3 | | |
| 7 | | | | .3 | | | 22 | 1.3 | | | | .1 | |
| 8 | | | | | .2 | | 23 | | 1.0 | .3 | | | .05 |
| 9 | | | .5 | | | .05 | 25 | | | | .45 | .1 | |
| 10 | | 1.1 | | .5 | | | 26 | 1.0 | 1.0 | | | | |
| 11 | | | | | .2 | | 27 | | | .3 | | | .05 |
| 12 | | (a) | | | | | 28 | | | | .45 | | |
| 13 | | | .45 | | | .05 | 29 | 1.0 | | | | .0 | |
| 15 | 1.3 | | | | | | 30 | | .9 | .3 | | | .25 |

a Dry.

**FARMERS AND CITIZENS DITCH NEAR JOSEPH, OREG.**

This ditch diverts water from the right bank of Wallowa River a few hundred feet below the head of the Silver Lake ditch.

The gage is vertical and is attached to the left side of the flume near the lower end.

The zero of the gage is the bottom of the flume. The gage was read twice a week by F. L. Bedingfield.

*Discharge measurements of Farmers and Citizens ditch near Joseph, Oreg., in 1905.*

| Date. | Hydrographer. | Width | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 11 | W. C. Sawyer | 11.4 | 22.4 | 3.06 | 1.93 | 68.5 |
| November 27 | R. S. Hall | 11.8 | 10.0 | 1.12 | .75 | 11.2 |

*Daily gage height, in feet, of Farmers and Citizens ditch near Joseph, Oreg., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | 0.65 | | 16 | | 1.5 | 0.8 | | | 0.5 |
| 2 | | 1.9 | 0.9 | | | 0.5 | 18 | | | | 0.7 | 0.6 | |
| 4 | | | | 0.7 | .7 | | 19 | 2.0 | 1.4 | | | | |
| 5 | | 1.9 | | | | | 20 | | | .8 | | | |
| 6 | | | .9 | | | .5 | 21 | | | | .7 | | |
| 7 | | | | .75 | | | 22 | 2.1 | | | | .7 | |
| 8 | | | | | .7 | | 23 | | 1.0 | .6 | | | .55 |
| 9 | | | .85 | | | .5 | 25 | | | | .7 | .5 | |
| 10 | | 1.9 | | .7 | | | 26 | .3 | .9 | | | | |
| 11 | | | | | .65 | | 27 | | | .6 | | | .5 |
| 12 | | 1.8 | | | | | 28 | | | | .65 | | |
| 13 | | | .85 | | | .5 | 29 | 1.7 | | | | .75 | |
| 15 | 1.9 | | | | | | 30 | | .9 | .7 | | | .4 |

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### GRANGER DITCH AT JOSEPH, OREG.

This ditch diverts water from the right bank of Wallowa River in the upper part of Joseph.

The gage is a vertical rod attached to the lower side of a wagon bridge a short distance below the lower end of the flume.

Gagings were made from this bridge.

*Discharge measurements of Granger ditch at Joseph, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 12 | W. C. Sawyer | 12.5 | 20.6 | 3.73 | 1.34 | 76.9 |
| November 27 | R. S. Hall | 13.8 | 9.4 | .98 | .30 | 9.1 |

*Daily gage height, in feet, of Granger ditch at Joseph, Oreg., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | 0.4 | | 16 | | 0.5 | 0.4 | | | 0.25 |
| 2 | | 2.2 | 0.4 | | | 0.3 | 18 | | | | 0.5 | 0.4 | |
| 4 | | | | 0.5 | .4 | | 19 | 0.6 | .4 | | | | |
| 5 | | 1.0 | | | | | 20 | | | .35 | | | |
| 6 | | | .4 | | | | 21 | | | | .5 | | |
| 7 | | | | .55 | | | 22 | 1.7 | | | | .4 | |
| 8 | | | | | .4 | | 23 | | .5 | .5 | | | .25 |
| 9 | | | .4 | | | .3 | 25 | | | | .5 | .35 | |
| 10 | | .4 | | .55 | | | 26 | 1.8 | .4 | | | | |
| 11 | | | | | .35 | | 27 | | | .6 | | | .25 |
| 12 | | .9 | | | | | 28 | | | | .4 | | |
| 13 | | | .4 | | | .3 | 29 | 1.8 | | | | .35 | |
| 15 | 1.0 | | | | | | 30 | | .35 | .5 | | | .25 |

### BIG BEND DITCH AT JOSEPH, OREG.

This ditch diverts water from the right bank of Wallowa River in the upper part of Joseph.

The gage is attached to the side of the flume near the lower end. The zero of the gage is the bottom of the flume.

Gagings were made from the wagon bridge below the end of the flume.

*Discharge measuzements of Big Bend ditch at Joseph, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 12 | W. C. Sawyer | 15.0 | 21.2 | 3.43 | 1.10 | 72.7 |
| November 27 | R. S. Hall | 12.5 | 5.2 | 1.57 | .40 | 8.2 |

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*Daily gage height, in feet, of Big Bend ditch at Joseph, Oreg., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Day. | July. | Aug. | Sept. | Oct. | Nov. | De |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | 0.5 | | 16 | | 0.25 | .25 | | | 0. |
| 2 | | 1.2 | 0.35 | | | 0.2 | 18 | | | | 0.5 | 0.6 | |
| 4 | | | | 0.3 | .6 | | 19 | 0.8 | .3 | | | | |
| 5 | | .7 | | | | | 20 | | | .55 | | | |
| 6 | | | .35 | | | .3 | 21 | | | | .5 | | |
| 7 | | | | .4 | | | 22 | 1.1 | | | | .0 | |
| 8 | | | | | .6 | | 23 | | .2 | 0.6 | | | .3 |
| 9 | | | .35 | | | .3 | 25 | | | | .45 | .65 | |
| 10 | | .3 | | .5 | | | 26 | .9 | .2 | | | | |
| 11 | | | | | .45 | | 27 | | | .7 | | | .2 |
| 12 | | .5 | | | | | 28 | | | | .45 | | |
| 13 | | | .5 | | | .3 | 29 | .9 | | | | .3 | |
| 15 | 0.9 | | | | | | 30 | | .3 | .55 | | | .2 |

### COMPANY DITCH NEAR WALLOWA, OREG.

This ditch diverts the water from the right bank of Wallowa River about 1,000 feet above the river gaging station.

The gage is a vertical rod on the right bank nearly opposite the river gaging station. Gagings were made from the bridge at the gage.

*Discharge measurements of Company ditch near Wallowa, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| May 19 | W. C. Sawyer | 13.8 | 1.78 | 2.60 | 24.6 |
| July 8 | do | 10.8 | 1.09 | 2.15 | 11.8 |
| September 18 | do | 8.3 | .77 | 1.82 | 6.4 |
| November 28 | R. S. Hall | 7.6 | 1.03 | 1.90 | 7.8 |

*Daily gage heights, in feet, of Company ditch near Wallowa, Oreg., for 1905.*

| Day. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|
| 2 | | | | | | 1.9 | | |
| 3 | | | | | | | 2.0 | |
| 4 | | | | | | | | 1.9 |
| 6 | | | | | | 1.85 | 1.95 | |
| 8 | | | 2.15 | | | | | 1.9 |
| 9 | | | | 1.7 | | 2.0 | | |
| 10 | | | | | | | 1.95 | |
| 11 | | | | | | | | 1.7 |
| 13 | | | | | | 2.0 | 1.9 | |
| 15 | | | | | 1.7 | | | |
| 16 | | | | | | 2.1 | | |
| 17 | | | | | | | 1.85 | |
| 18 | | | | | 1.82 | | | 1.8 |
| 19 | 2.6 | | | | | | | |
| 20 | | | | | | 2.0 | 1.95 | |
| 22 | | | | | 1.8 | | | |

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*Daily gage heights, in feet, of Company ditch near Wallowa, Oreg., for 1905*—Continued.

| Day. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|
| 3 | | | | | | 2.0 | | |
| 4 | | | | | | | 1.8 | |
| 5 | | | | | 1.75 | | | |
| 7 | | | | | | 2.05 | 2.0 | |
| 8 | | | | | | | 1.9 | |
| 9 | | | | | 2.0 | | | |
| 0 | | | | | | 2.0 | | |

*Estimated monthly discharge of Company ditch near Wallowa, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| May (22 days) | 25 | 25 | 25.0 | 1,091 |
| June | 35 | 35 | 35.0 | 2,083 |
| July | 20 | 6 | 11.5 | 707 |
| August | 8 | 5 | 5.55 | 341 |
| September | 9 | 5 | 5.9 | 351 |
| October | 11 | 7 | 8.87 | 545 |
| November | 9 | 6 | 7.93 | 472 |
| December | 12 | 5 | 7.32 | 450 |
| The period | | | | 6,040 |

NOTE.—Discharge estimated between May 10 and September 15.

## ASOTIN CREEK 1¼ MILES ABOVE ASOTIN, WASH.

This station was established March 26, 1904, by W. W. Schlecht. It is located at the highway bridge about 1¼ miles above Asotin, Wash., at the power house of the Lewiston Water and Power Company.

The channel is straight for about 120 feet above and 40 feet below the station, and the current is swift. Both banks are low and liable to overflow during extreme high water. They are both lined with brush, the left bank being covered with orchards and houses. The bed of the stream is composed of gravel and bowlders and is free from vegetation and fairly permanent. There is one channel at low and two channels at high stages.

Discharge measurements are made from the single-span bridge, to which the gage is attached. The initial point for soundings is a 20-penny nail driven into the floor of the bridge over the mean edge of the left abutment, and marked zero. At low water the current near the right bank may flow diagonally toward the center of the stream; at such times it is advisable to make the measurements from the upstream side of the bridge. During high stages the water at the upstream side is too swift for accurate measurements.

A staff gage is fastened vertically to the downstream face of the left abutment. During 1905 the gage was read once each day by M. E. Turner. Bench marks were established as follows: (1) A 20-penny nail driven horizontally into the guy pole for the chimney of the Lewiston Water and Power Company's power house, between the power house and the bridge, marked "U. S. G. S. B. M.;" elevation, 6.44 feet. (2) A 20-penny nail driven vertically into the stump of an old telegraph pole on the south side of the road, about 100 feet from the bridge, marked "U. S. G. S. B. M.;" elevation, 7.57 feet. Elevations refer to the datum of the gage.

A description of this station and gage height and discharge data are contained in Water-Supply Paper No. 135, United States Geological Survey, pages 237–239.

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*Daily gage height, in feet, of Asotin Creek 1¼ miles above Asotin, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.4 | 2.3 | 2.7 | 3.1 | 3.2 | 3.1 | 2.8 | 2.1 | 2.2 | 2.4 | 2.4 | 2.4 |
| 2 | 2.3 | 2.3 | 2.7 | 3.0 | 3.2 | 3.1 | 2.8 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 3 | 2.3 | 2.3 | 2.8 | 3.0 | 3.3 | 3.4 | 2.7 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 4 | 2.3 | 2.3 | 2.8 | 3.0 | 3.3 | 3.3 | 2.7 | 2.1 | 2.2 | 2.4 | 2.4 | 2.4 |
| 5 | 2.3 | 2.3 | 2.8 | 3.0 | 3.2 | 3.3 | 2.7 | 2.1 | 2.2 | 2.4 | 2.4 | 2.4 |
| 6 | 2.3 | 2.3 | 2.8 | 3.0 | 3.2 | 3.3 | 2.7 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 7 | 2.3 | 2.3 | 2.8 | 3.1 | 3.2 | 3.2 | 2.6 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 8 | 2.3 | 2.3 | 2.8 | 3.1 | 3.2 | 3.2 | 2.6 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 9 | 2.3 | 2.3 | 2.8 | 3.2 | 3.3 | 3.2 | 2.5 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 10 | 2.2 | 2.3 | 2.8 | 3.2 | 3.3 | 3.2 | 2.4 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 11 | 2.2 | 2.0 | 2.8 | 3.1 | 3.3 | 3.1 | 2.4 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 12 | 2.3 | 2.0 | 2.8 | 3.1 | 3.3 | 3.4 | 2.4 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 13 | 2.3 | 2.8 | 2.8 | 3.1 | 3.3 | 3.1 | 2.3 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 14 | 2.4 | 2.8 | 2.8 | 3.1 | 3.3 | 3.0 | 2.3 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 15 | 2.3 | 2.8 | 2.8 | 3.1 | 3.3 | 2.9 | 2.2 | 2.1 | 2.3 | 2.4 | 2.4 | 2.4 |
| 16 | 2.3 | 2.9 | 2.8 | 3.1 | 3.2 | 2.9 | 2.2 | 2.1 | 2.4 | 2.4 | 2.4 | 2.4 |
| 17 | 2.3 | 2.9 | 2.8 | 3.1 | 3.3 | 2.8 | 2.2 | 2.2 | 2.4 | 2.4 | 2.4 | 2.4 |
| 18 | 2.3 | 3.0 | 3.0 | 3.1 | 3.3 | 2.8 | 2.2 | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 |
| 19 | 2.3 | 2.9 | 3.0 | 3.1 | 3.2 | 2.8 | 2.2 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 |
| 20 | 2.2 | 3.1 | 3.0 | 3.3 | 3.2 | 2.7 | 2.2 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 |
| 21 | 2.2 | 3.1 | 3.0 | 3.2 | 3.2 | 2.7 | 2.1 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 |
| 22 | 2.2 | 2.7 | 3.0 | 3.2 | 3.2 | 2.6 | 2.1 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 |
| 23 | 2.2 | 2.6 | 3.0 | 3.2 | 3.2 | 2.7 | 2.1 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 |
| 24 | 2.4 | 2.6 | 3.0 | 3.3 | 3.1 | 2.8 | 2.1 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 |
| 25 | 2.3 | 2.6 | 3.0 | 3.3 | 3.1 | 2.9 | 2.1 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 |
| 26 | 2.3 | 2.6 | 3.3 | 3.3 | 3.1 | 3.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.4 | 2.4 |
| 27 | 2.3 | 2.7 | 3.2 | 3.2 | 3.1 | 3.0 | 2.1 | 2.2 | 3.1 | 2.4 | 2.4 | 2.4 |
| 28 | 2.3 | 2.7 | 3.2 | 3.2 | 3.1 | 3.0 | 2.1 | 2.2 | 2.7 | 2.4 | 2.4 | 2.4 |
| 29 | 2.3 | ..... | 3.2 | 3.2 | 3.1 | 2.8 | 2.1 | 2.2 | 2.5 | 2.4 | 2.4 | 2.4 |
| 30 | 2.3 | ..... | 3.2 | 3.2 | 3.1 | 2.8 | 2.1 | 2.2 | 2.5 | 2.4 | 2.4 | 2.4 |
| 31 | 2.3 | ..... | 3.1 | ..... | 3.1 | ..... | 2.1 | 2.2 | ..... | 2.4 | 2.4 | 2.4 |

NOTE.—No ice record.

## ASOTIN CREEK AT SHELMAN'S RANCH, NEAR ASOTIN, WASH.

This station was established March 25, 1904, by W. W. Schlecht. It is located at Shelman's ranch, about 8 miles above Asotin, Wash. The station is 50 feet above the headgate of Shelman's irrigation ditch.

The channel is straight for about 100 feet above and below the station and the current is swift. The right bank is a flood plain about 350 feet wide, which may be flooded at extreme high water. The left bank is a similar plain about 120 feet wide, which overflows during high water. Both banks are lined with trees and brush. The bed of the stream is composed of gravel and bowlders and is free from vegetation and fairly permanent. There is one channel at ordinary and two at extreme high stages.

Discharge measurements are made by means of a cable, car, and tagged wire. The initial point for soundings is a nail driven into a hub below the cable support on the left bank.

A staff gage is fastened to a tree on the left bank. During 1905 the gage was read once each day by J. W. Whittaker. The bench mark is the top of a 40-penny nail driven horizontally into a large willow tree about 40 feet west of Shelman's house, 2 feet north of the road, marked "U. S. G. S. B. M.;" elevation, 10.00 feet above the datum of the gage.

A description of this station, with gage heights and discharge data, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 239–240.

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*Daily gage height, in feet, of Asotin Creek at Shelman's ranch, near Asotin, Wash., for 1905.*

| Day. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.7 | 1.82 | 1.85 | 1.7 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 2 | 1.7 | 1.78 | 1.92 | 1.65 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 3 | 1.7 | 1.8 | 2.6 | 1.62 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 4 | 1.65 | 1.8 | 2.5 | 1.65 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 5 | 1.65 | 1.8 | 2.47 | 1.62 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 6 | 1.65 | 1.8 | 2.45 | 1.6 | 1.45 | 1.45 | 1.5 | 1.45 | 1.5 |
| 7 | 1.75 | 1.8 | 2.45 | 1.55 | 1.45 | 1.45 | 1.5 | 1.45 | 1.5 |
| 8 | 1.75 | 1.8 | 2.45 | 1.55 | 1.45 | 1.45 | 1.5 | 1.48 | 1.5 |
| 9 | 1.77 | 1.8 | 2.42 | 1.55 | 1.45 | 1.45 | 1.5 | 1.5 | 1.45 |
| 10 | 1.75 | 1.82 | 2.38 | 1.55 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 11 | 1.75 | 1.85 | 2.35 | 1.55 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 12 | 1.75 | 1.8 | 2.5 | 1.5 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 13 | 1.75 | 1.8 | 2.5 | 1.5 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 14 | 1.7 | 1.8 | 2.45 | 1.5 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 15 | 1.72 | 1.82 | 2.4 | 1.5 | 1.45 | 1.45 | 1.5 | 1.45 | 1.5 |
| 16 | 1.7 | 1.85 | 2.37 | 1.5 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 17 | 1.7 | 1.9 | 2.27 | 1.5 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 18 | 1.7 | 1.9 | 2.25 | 1.5 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 19 | 1.8 | 1.9 | 2.25 | 1.5 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 |
| 20 | 1.8 | 1.9 | 2.25 | 1.5 | 1.45 | 1.45 | 1.5 | 1.45 | 1.5 |
| 21 | 1.82 | 1.85 | 2.25 | 1.5 | 1.45 | 1.45 | 1.5 | 1.48 | 1.45 |
| 22 | 1.82 | 1.85 | 2.25 | 1.45 | 1.45 | 1.45 | 1.5 | 1.5 | 1.45 |
| 23 | 1.8 | 1.85 | 2.25 | 1.45 | 1.45 | 1.45 | 1.5 | 1.5 | 1.45 |
| 24 | 1.82 | 1.8 | 2.25 | 1.45 | 1.45 | 1.45 | 1.5 | 1.5 | 1.45 |
| 25 | 1.85 | 1.8 | 2.62 | 1.45 | 1.45 | 1.45 | 1.55 | 1.5 | 1.45 |
| 26 | 1.85 | 1.8 | 1.82 | 1.45 | 1.45 | 1.5 | 1.5 | 1.5 | 1.55 |
| 27 | 1.85 | 1.75 | 2.25 | 1.45 | 1.45 | 1.65 | 1.5 | 1.5 | 1.5 |
| 28 | 1.85 | 1.8 | 1.7 | 1.45 | 1.45 | 1.6 | 1.5 | 1.5 | 1.5 |
| 29 | 1.85 | 1.85 | 1.72 | 1.45 | 1.45 | 1.5 | 1.55 | 1.5 | 1.5 |
| 30 | 1.85 | 1.85 | 1.6 | 1.45 | 1.45 | 1.5 | 1.55 | 1.5 | 1.5 |
| 31 | ..... | 1.85 | ..... | 1.45 | 1.45 | ..... | 1.5 | ..... | 1.45 |

## PALOUSE RIVER AT ELBERTON, WASH.

This station was established May 6, 1904, by W. G. Steward, and was discontinued September 30, 1905, owing to changes in the dam near by. It is located at the highway bridge about one-half mile above the depot in Elberton, Wash.

The west channel is straight for about 1,500 feet above and below the station. The current is swift. The east channel leaves the main (west) channel about 150 feet above the station and makes a reverse curve, striking the bridge at an angle of about 30°. The east channel is straight for 300 feet below and curved above the station. At high water the current is swift; at low water there is no flow in this channel. The right bank is high and not liable to overflow except in case of extreme high water, in which case the town would be flooded. The left bank is low and overflows during high water along the roadway to the east of the east channel. The bed of the stream is composed of rock and gravel, is free from vegetation, and is shifting. All the water flows in one channel at low and in two at high stages.

Discharge measurements are made for the west channel from the upstream side of the bridge. For the east channel measurements are made from the downstream side of the bridge. The initial point for the west channel is a point on the guard rail immediately above the face of the left abutment. The initial point for the east channel is the left end of the downstream hand rail. Both initial points are marked zero with nails and black paint.

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A staff gage is fastened vertically to the south end of the face of the left abutment of the bridge. During 1905 the gage was read once each day by W. B. Peoples. Bench marks were established as follows: (1) A 20-penny nail in a large white post on the south side of the railroad track, about one-fourth mile east of the depot; elevation, 2,198.05 feet above sea level and 5.80 feet above the datum of the gage. (2) A square black-paint mark on the southeast window sill of the hotel; elevation, 2,203.91 feet above sea level and 11.66 feet above the datum of the gage. (3) The head of a rivet in the base of the bridge truss at the southwest corner of the bridge, painted "U. S. G. S." on the plate; elevation, 2,206.01 feet above sea level and 13.76 feet above the datum of the gage.

May 24, 1905, a discharge measurement made at this station by W. J. Lightfoot gave the following results: Width, 68 feet; area of section, 116 square feet; mean velocity, 1.93 feet per second; gage height, 2.3 feet; discharge, 224 second-feet.

A description of this station, with gage heights, discharge data, and rating table, is contained in Water-Supply Paper No. 135, United States Geological Survey, pages 240–243.

*Daily gage height, in feet, of Palouse River at Elberton, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.7 | 1.8 | 2.0 | 2.3 | 2.0 | 2.2 | 1.6 | 0.8 | 0.7 |
| 2 | 1.9 | 1.8 | 2.2 | 2.10 | 1.9 | 2.0 | 1.6 | 1.0 | .7 |
| 3 | 1.8 | 1.8 | 2.0 | 2.0 | 2.0 | 1.5 | 1.6 | .9 | .7 |
| 4 | 1.7 | 1.8 | 1.9 | 2.5 | 2.0 | 2.3 | 1.4 | .8 | .7 |
| 5 | 1.6 | 1.8 | 2.7 | 2.2 | 1.9 | 3.0 | 1.1 | .8 | .7 |
| 6 | 2.0 | 1.8 | 1.7 | 2.0 | 1.4 | 2.7 | 1.1 | .8 | .7 |
| 7 | 1.9 | 1.9 | 2.6 | 1.7 | 1.3 | 3.5 | 2.1 | .7 | .7 |
| 8 | 1.7 | 1.8 | 2.0 | 2.4 | 1.9 | 3.0 | 1.3 | .7 | .7 |
| 9 | 1.7 | 1.8 | 1.8 | 2.3 | 1.4 | 2.9 | 1.5 | .7 | .7 |
| 10 | 1.7 | 1.7 | 2.0 | 2.3 | 1.9 | 2.6 | 1.3 | 1.2 | .7 |
| 11 | 1.7 | 1.6 | 2.6 | 2.3 | 1.4 | 2.4 | 1.1 | .9 | .7 |
| 12 | 1.7 | 1.6 | 1.7 | 2.3 | 2.2 | 2.3 | 1.4 | .7 | .7 |
| 13 | 1.6 | 1.6 | 1.7 | 2.4 | 2.5 | 2.2 | 1.1 | .8 | .7 |
| 14 | 1.6 | 1.6 | 2.0 | 2.0 | 2.0 | 2.0 | .9 | .7 | .7 |
| 15 | 1.6 | 1.6 | 1.7 | 1.7 | 2.0 | 2.0 | 1.2 | .7 | .8 |
| 16 | 1.7 | 1.6 | 1.7 | 2.5 | 2.0 | 1.9 | 1.0 | .7 | .8 |
| 17 | 1.6 | 1.6 | 1.8 | 1.7 | 2.0 | 1.3 | 1.0 | .7 | .8 |
| 18 | 1.5 | 1.6 | 2.7 | 1.8 | 2.0 | 1.6 | 1.4 | 1.0 | .8 |
| 19 | 1.7 | 1.6 | 1.9 | 2.4 | 1.5 | 1.2 | 1.1 | .8 | .9 |
| 20 | 1.7 | 1.6 | 1.7 | 3.5 | 2.3 | 2.15 | 1.0 | .5 | .8 |
| 21 | 1.6 | 1.6 | 3.3 | 3.6 | 2.0 | 1.8 | 1.1 | .7 | .8 |
| 22 | 1.6 | 1.8 | 1.6 | 2.0 | 2.2 | 1.2 | 1.1 | .7 | .9 |
| 23 | 1.7 | 1.8 | 2.6 | 2.4 | 2.3 | 1.2 | .8 | .7 | 1.0 |
| 24 | 1.9 | 1.8 | 1.8 | 2.0 | 2.3 | 1.6 | 1.2 | .7 | 1.4 |
| 25 | 1.8 | 1.8 | 3.7 | 3.7 | 2.9 | 1.1 | 1.0 | .6 | 1.4 |
| 26 | 1.8 | 2.0 | 2.9 | 2.3 | 3.3 | 1.2 | 1.3 | .6 | 1.4 |
| 27 | 1.9 | 2.2 | 3.7 | 2.4 | 2.9 | 1.8 | 1.1 | .6 | 1.3 |
| 28 | 1.9 | 2.0 | 2.7 | 2.2 | 1.8 | 2.0 | 1.1 | 1.1 | 1.2 |
| 29 | 1.9 | ..... | 3.0 | 2.0 | 2.8 | 1.8 | .9 | .9 | 1.0 |
| 30 | 2.0 | ..... | 2.5 | 2.0 | 2.5 | 1.7 | .9 | .9 | 1.0 |
| 31 | 2.0 | ..... | 2.4 | ..... | 2.5 | ..... | .9 | .8 | ..... |

NOTE.—Sudden changes are due to flow being controlled by dam.

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## PALOUSE RIVER AT HOOPER, WASH.

The headwater tributaries of this river have their sources in western Idaho. After reaching Washington they unite to form Palouse River, which flows in a general southwesterly direction through a rolling country. Six miles below Hooper, Wash., the river bends suddenly to the south and enters its canyon, through which it flows to its junction with Snake River. For some distance above Hooper the river consists of a succession of pools from 10 to 15 feet in depth, connected by short riffles. Its valley is about one-half mile in width and bordered with basaltic cliffs approximately 300 feet in height. A short distance above the mouth of the river are the Palouse Falls, which are approximately 130 feet in height.

The measurements of Palouse River are of value in showing the amount of water that could be utilized for irrigation on lands of Washtucna Valley and in the section north of Pasco.

The gaging station at Hooper, Wash., was originally established April 1, 1897, by the land department of the Northern Pacific Railway. The United States Geological Survey assumed charge September 9, 1897, and moved the station about 1 mile downstream.

The channel is straight for 200 feet above and one-fourth of a mile below the cable. The current is swift. The left bank is high and can not overflow. The right bank overflows during high stages of the river. Both banks are covered with brush. The bed of the stream is rocky and free from vegetation, but bowlders in the bed make it difficult to obtain accurate results at this point at low water. There is but one channel at all stages.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is the cable post on the left bank.

Owing to various conditions it has been necessary to use several gages, all having the same datum. The present gage, known as gage No. 4, is in two sections. The lower section is inclined, the upper is vertical. During 1905 the gage was read once each day by Frank Hill. Bench marks were established as follows: (1) The highest point on a ledge of rock on the left bank 200 feet below the cable; elevation, 7.60 feet. (2) The top of a large rock on the right bank 250 feet west of the cable post and 115 feet from the water's edge; elevation, 10.88 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; WS=Water-Supply Paper):

Description: WS 16, p 172; 28, p 155; 38, pp 360-361; 51, p 443; 66, p 136; 85, pp 203-204; 100, pp 413-414; 135, pp 243-244.
Discharge: Ann 19, iv, p 460; WS 16, p 172; 28, p 168; 51, p 444; 85, p 204; 100, p 414; 135, p 245.
Discharge, monthly: Ann 20, iv, pp 489, 514; 21, iv, p 414; 22, iv, p 452; WS 75, p 206; 85, p 205; 135, p. 247.
Discharge, yearly: Ann 20, iv, p 62.
Gage heights: WS 16, p 172; 28, p 162; 38, p 361; 51, p 444; 66, p 137; 85, p 204; 100, p 415; 135, pp 245-246.
Hydrographs: Ann 20, iv, p 490; 21, iv, p 415; 22, iv, p 452.
Rainfall and run-off relation: Ann 20, iv, p 514.
Rating tables. WS 28, p 170; 39, p 454; 52, p 522; 66, p 177; 85, p 205; 135, p 246.

*Discharge measurements of Palouse River at Hooper, Wash., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet* | *Feet per second* | *Feet.* | *Second-feet.* |
| May 18 | W. J. Lightfoot | 84 | 153 | 1.72 | 2.30 | 264 |
| November 23 | W. C. Sawyer | 66 | 74 | .74 | 1.13 | 55 |

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*Daily gage height, in feet, of Palouse River at Hooper, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.6 | 2.55 | 2.5 | 3.8 | 2.4 | 2.75 | 1.85 | 0.85 | 0.65 | 0.8 | 1.3 | 1.45 |
| 2 | 2.0 | 3.0 | 2.5 | 3.8 | 2.3 | 2.45 | 1.85 | .85 | .65 | .95 | 1.1 | 2.35 |
| 3 | 1.75 | 2.2 | 2.45 | 3.4 | 2.3 | 2.6 | 1.8 | .85 | .65 | 1.0 | 1.35 | 1.95 |
| 4 | 1.7 | 2.7 | 2.4 | 2.85 | 2.3 | 2.4 | 1.75 | .8 | .65 | 1.0 | 1.3 | 1.6 |
| 5 | 2.05 | 2.45 | 2.3 | 3.1 | 2.25 | 2.0 | 1.6 | .8 | .6 | 1.0 | 1.4 | 1.45 |
| 6 | 1.75 | 2.3 | 2.15 | 2.9 | 2.2 | 2.55 | 1.55 | .8 | .6 | 1.4 | 1.65 | 1.55 |
| 7 | 1.5 | 2.3 | 2.55 | 2.65 | 2.1 | 3.0 | 1.45 | .8 | .6 | 1.3 | 1.55 | 1.7 |
| 8 | 1.5 | 2.2 | 2.25 | 2.6 | 2.0 | 3.75 | 1.35 | .8 | .6 | 1.6 | 1.45 | 1.6 |
| 9 | 1.5 | 2.1 | 2.65 | 2.65 | 1.85 | 3.35 | 1.35 | .8 | .6 | 1.7 | 1.35 | 2.0 |
| 10 | 1.45 | 2.05 | 2.5 | 2.8 | 2.10 | 3.1 | 1.4 | .8 | .6 | 1.5 | 1.2 | 1.75 |
| 11 | 1.4 | [a]3.1 | 2.3 | 2.6 | 2.0 | 2.85 | 1.4 | .8 | .6 | 1.5 | 1.2 | 1.55 |
| 12 | 1.4 | 1.8 | 2.3 | 2.55 | 2.1 | 2.7 | 1.3 | .75 | .6 | 1.45 | 1.3 | 1.45 |
| 13 | 1.4 | 1.8 | 2.55 | 2.55 | 2.05 | 2.5 | 1.25 | .75 | .6 | 1.3 | 1.2 | 1.4 |
| 14 | 1.4 | 1.95 | 2.1 | 2.5 | 2.6 | 2.35 | 1.2 | .75 | .65 | 1.4 | 1.2 | 1.4 |
| 15 | 1.3 | 1.9 | 2.4 | 2.5 | 3.0 | 2.3 | 1.2 | .75 | .7 | 1.4 | 1.2 | 1.5 |
| 16 | 1.3 | 1.95 | 2.15 | 2.2 | 2.6 | 2.15 | 1.2 | .75 | .7 | 1.4 | 1.4 | 1.5 |
| 17 | 1.45 | 1.9 | 2.45 | 2.15 | 3.1 | 2.05 | 1.2 | .75 | .7 | 1.35 | 1.5 | 1.6 |
| 18 | 1.5 | 1.95 | 2.1 | 2.55 | 2.3 | 2.0 | 1.15 | .75 | .7 | 1.35 | 1.4 | 1.75 |
| 19 | 1.5 | 1.9 | 2.05 | 2.25 | 2.95 | 1.75 | 1.15 | .75 | .7 | 1.3 | 1.35 | 1.65 |
| 20 | 1.5 | 2.0 | 2.6 | 2.35 | 2.2 | 1.95 | 1.15 | .75 | .7 | 1.3 | 1.3 | 1.8 |
| 21 | 1.5 | 1.95 | 2.35 | 2.65 | 1.9 | 1.70 | 1.1 | .75 | .7 | 1.3 | 1.25 | 1.75 |
| 22 | 1.5 | 1.95 | 2.8 | 2.95 | 2.3 | 1.55 | 1.1 | .7 | .7 | 1.7 | 1.2 | 1.75 |
| 23 | 1.6 | 2.05 | 2.8 | 2.95 | 2.95 | 2.05 | 1.1 | .7 | .7 | 1.5 | 1.1 | 1.7 |
| 24 | 2.45 | 2.15 | 2.5 | 3.75 | 2.35 | 1.70 | 1.05 | .7 | .7 | 1.4 | 1.25 | 1.6 |
| 25 | 3.45 | 2.45 | 2.6 | 3.3 | 2.45 | 1.6 | 1.05 | .7 | .7 | 1.3 | 1.35 | 1.95 |
| 26 | 3.0 | 2.4 | 2.75 | 3.2 | 2.5 | 2.15 | 1.0 | .7 | .7 | 1.2 | 1.35 | 1.8 |
| 27 | 2.75 | 2.4 | 3.3 | 3.2 | 3.45 | 1.8 | 1.9 | .7 | .75 | 1.2 | 1.25 | 2.0 |
| 28 | 2.7 | 2.45 | 4.2 | 2.6 | 3.25 | 1.65 | .85 | .7 | .75 | 1.5 | 1.2 | 1.7 |
| 29 | 2.85 | ..... | 4.2 | 2.5 | 3.25 | 2.0 | .85 | .65 | .75 | 1.65 | 1.35 | 1.5 |
| 30 | 2.8 | ..... | 4.1 | 2.45 | 2.6 | 1.7 | .85 | .65 | .75 | 1.4 | 1.4 | 1.6 |
| 31 | 2.7 | ..... | 3.7 | ..... | 2.6 | ..... | .85 | .65 | ..... | 1.35 | ..... | 1.5 |

[a] Backwater from ice gorge.

*Station rating table for Palouse River at Hooper, Wash., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.60 | 19 | 1.60 | 116 | 2.50 | 296 | 3.40 | 540 |
| 0.70 | 24 | 1.70 | 132 | 2.60 | 320 | 3.50 | 570 |
| 0.80 | 30 | 1.80 | 150 | 2.70 | 344 | 3.60 | 602 |
| 0.90 | 36 | 1.90 | 168 | 2.80 | 370 | 3.70 | 634 |
| 1.00 | 44 | 2.00 | 188 | 2.90 | 396 | 3.80 | 666 |
| 1.10 | 52 | 2.10 | 208 | 3.00 | 424 | 3.90 | 700 |
| 1.20 | 62 | 2.20 | 228 | 3.10 | 452 | 4.00 | 734 |
| 1.30 | 74 | 2.30 | 250 | 3.20 | 480 | 4.10 | 768 |
| 1.40 | 88 | 2.40 | 272 | 3.30 | 510 | 4.20 | 802 |
| 1.50 | 102 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1904–5. It is not well defined.

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*Estimated monthly discharge of Palouse River at Hooper, Wash., for 1905.*

[Drainage area, 2,210 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet. | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| January | 555 | 74 | 181 | 11,130 | 0.082 | 0.094 |
| February | 424 | 150 | 225 | 12,500 | .102 | .106 |
| March | 802 | 198 | 348 | 21,400 | .157 | .181 |
| April | 666 | 218 | 380 | 22,610 | .172 | .192 |
| May | 555 | 159 | 294 | 18,080 | .133 | .153 |
| June | 650 | 109 | 258 | 15,350 | .117 | .130 |
| July | 159 | 33 | 73.9 | 4,544 | .033 | .038 |
| August | 33 | 22 | 27.2 | 1,672 | .012 | .014 |
| September | 27 | 19 | 22.2 | 1,321 | .010 | .011 |
| October | 132 | 30 | 82.2 | 5,054 | .037 | .043 |
| November | 124 | 52 | 76.9 | 4,576 | .035 | .039 |
| December | 261 | 88 | 126 | 7,747 | .057 | .066 |
| The year | 802 | 19 | 175 | 126,000 | .079 | 1.07 |

NOTE.—Owing to backwater February 11, the discharge was interpolated between the discharges for February 10 and 12.

## ROCK CREEK NEAR ST. JOHN, WASH.

This station was established October 15, 1903, by G. H. Bliss, and discontinued September 30, 1905. It is located at the highway bridge which crosses Rock Creek at the outlet of Rock Lake, three-fourths of a mile from the ranch of the observer, C. K. Reimer. It is 9 miles northeast of St. John, Whitman County, Wash.

The channel is straight for 200 feet above and 75 feet below the station. The current is sluggish at the bridge at low stages. Both banks are low and rocky and liable to overflow at flood stages. The bed of the stream is covered with rocks and gravel and is liable to shift at flood stages.

At high stages discharge measurements are made from the downstream side of the highway bridge. At low stages they are made by wading below the bridge. The bridge is supported by pile bents and has a total span of 210 feet. The initial point for soundings is the end post of the downstream handrail.

The gage is a vertical rod fastened to the fifth pile bent of the southeast (left) bank approach. Bench marks were established as follows: (1) A spike driven into the downstream side of the top of the sill of the third pile bent from the left-bank approach; elevation, 12.52 feet. (2) The top of a large rock on a point of rocks on the southeast side of the lake about 3,000 feet above the outlet; elevation, 16.70 feet. Elevations refer to the datum of the gage.

May 20, 1905, a discharge measurement made at this station by W. J. Lightfoot gave the following results: Width, 111 feet; area of section, 76 square feet; mean velocity, 0.29 foot per second; gage height, 10.8 feet; discharge, 22 second-feet.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey.

Description: 100, pp 415-416; 135, pp 247-248.
Discharge: 100, p 416; 135, p 248.
Discharge, monthly: 135, p 249.
Gage heights: 100, p 416; 135, p 248.
Rating table: 135, p 249.

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*Daily gage height, in feet, of Rock Creek near St. John, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 10.54 | 12.05 | 11.42 | 11.38 | 11.18 | 10.8 | 10.72 | 10.34 | 9.9 |
| 2 | 10.6 | 11.95 | 11.42 | 11.38 | 11.18 | 10.8 | 10.72 | 10.32 | 9.9 |
| 3 | 10.6 | 11.95 | 11.4 | 11.38 | 11.16 | 10.85 | 10.7 | 10.3 | 9.8 |
| 4 | 10.62 | 11.95 | 11.4 | 11.38 | 11.16 | 10.85 | 10.7 | 10.28 | 9.8 |
| 5 | 10.62 | 11.9 | 11.4 | 11.38 | 11.16 | 10.85 | 10.68 | 10.26 | 9.8 |
| 6 | 10.65 | 11.85 | 11.4 | 11.38 | 11.16 | 10.85 | 10.68 | 10.24 | 9.8 |
| 7 | 10.65 | 11.8 | 11.38 | 11.38 | 11.14 | 10.85 | 10.65 | 10.22 | 9.8 |
| 8 | 10.65 | 11.75 | 11.38 | 11.38 | 11.14 | 10.82 | 10.65 | 10.2 | 9.8 |
| 9 | 10.68 | 11.75 | 11.38 | 11.35 | 11.12 | 10.82 | 10.62 | 10.18 | 9.8 |
| 10 | 10.68 | 11.75 | 11.38 | 11.35 | 11.12 | 10.8 | 10.62 | 10.16 | 9.8 |
| 11 | 10.68 | 11.7 | 11.38 | 11.33 | 11.1 | 10.8 | 10.6 | 10.14 | 9.8 |
| 12 | 10.68 | 11.65 | 11.35 | 11.32 | 11.1 | 10.8 | 10.6 | 10.12 | 9.8 |
| 13 | 10.68 | 11.6 | 11.35 | 11.3 | 11.08 | 10.8 | 10.58 | 10.1 | 9.8 |
| 14 | 10.7 | 11.55 | 11.3 | 11.3 | 11.08 | 10.78 | 10.55 | 10.1 | 9.8 |
| 15 | 10.7 | 11.5 | 11.3 | 11.28 | 11.04 | 10.78 | 10.52 | 10.08 | 9.8 |
| 16 | 10.7 | 11.46 | 11.28 | 11.28 | 11.0 | 10.75 | 10.5 | 10.08 | 9.8 |
| 17 | 10.7 | 11.4 | 11.25 | 11.28 | 11.0 | 10.75 | 10.5 | 10.06 | 9.8 |
| 18 | 10.7 | 11.4 | 11.25 | 11.27 | 10.95 | 10.75 | 10.5 | 10.06 | 9.8 |
| 19 | 10.7 | 11.4 | 11.25 | 11.25 | 10.9 | 10.72 | 10.5 | 10.05 | 9.8 |
| 20 | 10.7 | 11.4 | 11.25 | 11.25 | 10.85 | 10.72 | 10.48 | 10.04 | 9.8 |
| 21 | 10.7 | 11.4 | 11.25 | 11.23 | 10.8 | 10.72 | 10.48 | 10.02 | 9.78 |
| 22 | 10.7 | 11.4 | 11.25 | 11.23 | 10.8 | 10.7 | 10.48 | 10.02 | 9.78 |
| 23 | 10.85 | 11.4 | 11.25 | 11.22 | 10.8 | 10.7 | 10.45 | 10.0 | 9.78 |
| 24 | 11.35 | 11.4 | 11.3 | 11.22 | 10.8 | 10.7 | 10.45 | 10.0 | 9.78 |
| 25 | 12.0 | 11.42 | 11.35 | 11.2 | 10.8 | 10.8 | 10.45 | 10.0 | 9.76 |
| 26 | 12.12 | 11.42 | 11.35 | 11.2 | 10.8 | 10.8 | 10.42 | 9.98 | 9.76 |
| 27 | 12.18 | 11.45 | 11.38 | 11.2 | 10.8 | 10.78 | 10.42 | 9.98 | 9.76 |
| 28 | 12.2 | 11.45 | 11.4 | 11.18 | 10.8 | 10.75 | 10.4 | 9.96 | 9.76 |
| 29 | 12.2 | ..... | 11.4 | 11.18 | 10.8 | 10.75 | 10.38 | 9.94 | 9.76 |
| 30 | 12.2 | ..... | 11.4 | 11.18 | 10.8 | 10.74 | 10.38 | 9.92 | 9.76 |
| 31 | 12.15 | ..... | 11.38 | ..... | 10.8 | ..... | 10.36 | 9.92 | ..... |

*Station rating table for Rock Creek near St. John, Wash., from October 15, 1903, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 10.00 | 0.0 | 10.60 | 14 | 11.20 | 59 | 11.80 | 134 |
| 10.10 | .5 | 10.70 | 19 | 11.30 | 70 | 11.90 | 149 |
| 10.20 | 1.5 | 10.80 | 25 | 11.40 | 82 | 12.00 | 165 |
| 10.30 | 3 | 10.90 | 32 | 11.50 | 94 | 12.10 | 183 |
| 10.40 | 6 | 11.00 | 40 | 11.60 | 107 | 12.20 | 203 |
| 10.50 | 10 | 11.10 | 49 | 11.70 | 120 | 14.00 | 940 |

The above table is applicable only for open-channel conditions. It is based on eight discharge measurements made during 1903-1905. It is well defined.

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*Estimated monthly discharge of Rock Creek near St. John, Wash., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 203 | 12 | 59.2 | 3,640 |
| February | 174 | 82 | 110 | 6,109 |
| March | 84 | 64 | 75.2 | 4,624 |
| April | 80 | 57 | 69.0 | 4,106 |
| May | 57 | 25 | 39.6 | 2,435 |
| June | 28 | 19 | 23.7 | 1,410 |
| July | 20 | 5 | 11.8 | 726 |
| August | 4 | 0 | .89 | 55 |
| September | 0 | 0 | .00 | 0 |
| The period | | | | 23,100 |

## COW CREEK NEAR KEYSTONE, WASH.

This station was established November 10, 1904, by Calvin Casteel, and discontinued September 30, 1905. It is located at the highway bridge on the Sprague-Ritzville road crossing of Cow Creek, 2¼ miles east of Keystone, Wash., and one-fourth mile southeast of Lakeview schoolhouse. The station is a short distance below the foot of Colville Lake.

The channel is straight for about 200 feet above and 100 feet below the station. The current above the station is moderate at ordinary and sluggish at low stages; below the station it is swift at all stages. Both banks are high, clean, and not liable to overflow. The bed of the stream is composed of rock and gravel and is permanent. There is but one channel at all stages.

Discharge measurements are made from the upstream side of the single-span bridge. The bridge is 18.6 feet long between abutments. The initial point for soundings is a nail driven into the end of a plank on the deck of the bridge above the edge of the abutment.

A staff gage is fastened vertically to a post of the bridge at the upper left end. During 1905 the gage was read once each day by S. A. Fulquartz. The bench mark is a United States Geological Survey standard aluminum tablet set in a large bowlder, 125 feet up Cow Creek from the Sprague-Ritzville road Crossing, on the right bank; elevation, 1,883.15 feet above sea level and 4.19 feet above the datum of the gage.

May 15, 1905, a discharge measurement made at this station by W. J. Lightfoot gave the following results: Width, 18.6 feet; area of section, 12 square feet; mean velocity, 1.08 feet per second; gage height, 0.90 foot; discharge, 13 second-feet.

A description of this station, with gage heights and discharge data, is contained in Water-Supply Paper No. 135, United States Geological Survey, page 250.

*Daily gage height, in feet, of Cow Creek near Keystone, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.87 | 1.25 | 1.06 | 1.01 | 0.9 | 0.76 | 0.65 | 0.27 | 0.0 |
| 2 | .88 | 1.18 | 1.06 | 1.01 | .9 | .74 | .63 | .26 | .0 |
| 3 | .88 | 1.13 | 1.06 | 1.0 | .89 | .78 | .6 | .25 | .0 |
| 4 | .87 | 1.09 | 1.06 | .99 | .89 | .79 | .57 | .24 | .0 |
| 5 | .88 | 1.08 | 1.06 | .98 | .87 | .8 | .55 | .24 | .0 |
| 6 | .89 | 1.06 | 1.05 | .98 | .87 | .81 | .54 | .21 | .0 |
| 7 | .89 | 1.05 | 1.05 | .97 | .88 | .82 | .52 | .18 | .0 |
| 8 | .88 | 1.12 | 1.05 | .97 | .87 | .82 | .51 | .17 | .0 |
| 9 | .88 | 1.15 | 1.05 | .96 | .87 | .81 | .5 | .14 | .0 |
| 10 | .90 | 1.2 | 1.06 | .95 | .88 | .81 | .5 | .12 | .0 |
| 11 | .94 | 1.22 | 1.07 | .95 | .88 | .79 | .48 | .10 | .0 |
| 12 | .98 | 1.1 | 1.09 | .9 | .89 | .75 | .45 | .04 | .0 |
| 13 | .98 | 1.0 | 1.1 | .9 | .89 | .7 | .42 | .02 | .0 |

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*Daily gage height, in feet, of Cow Creek near Keystone, Wash., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 14 | 0.98 | 1.02 | 1.08 | 0.91 | 0.89 | 0.66 | 0.41 | 0.01 | 0.0 |
| 15 | .98 | 1.01 | 1.05 | .92 | .88 | .66 | .4 | .0 | .0 |
| 16 | .9 | 1.0 | 1.02 | .94 | .88 | .67 | .4 | .0 | .0 |
| 17 | .88 | .98 | 1.0 | .96 | .88 | .67 | .39 | .0 | .0 |
| 18 | .88 | .98 | .99 | .97 | .87 | .66 | .39 | .0 | .0 |
| 19 | .89 | .99 | .99 | .97 | .87 | .66 | .38 | .0 | .0 |
| 20 | .9 | 1.01 | .98 | .97 | .87 | .67 | .37 | .0 | .0 |
| 21 | .91 | 1.02 | .98 | .96 | .84 | .66 | .37 | .0 | .0 |
| 22 | .9 | 1.04 | .99 | .96 | .8 | .67 | .36 | .0 | .0 |
| 23 | .89 | 1.07 | .99 | .97 | .79 | .68 | .35 | .0 | .0 |
| 24 | .89 | 1.07 | .98 | .97 | .79 | .7 | .32 | .0 | .0 |
| 25 | .95 | 1.08 | .98 | .98 | .8 | .68 | .32 | .0 | .0 |
| 26 | 1.0 | 1.07 | .99 | .97 | .79 | .67 | .3 | .0 | .0 |
| 27 | 1.07 | 1.06 | 1.0 | .96 | .78 | .67 | .31 | .0 | .0 |
| 28 | 1.08 | 1.06 | 1.0 | .97 | .78 | .66 | .32 | .0 | .0 |
| 29 | 1.06 | ..... | 1.01 | .98 | .77 | .65 | .33 | .0 | .0 |
| 30 | 1.04 | ..... | 1.01 | .9 | .77 | .65 | .31 | .0 | .0 |
| 31 | 1.25 | ..... | 1.0 | ..... | .76 | ..... | .29 | .0 | .0 |

## WALLA WALLA RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Walla Walla River, the drainage basin of which is one of the best irrigated and most productive localities in either Washington or Oregon, enters Columbia River from the east near the town of Wallula, Wash.

### SOUTH FORK OF WALLA WALLA RIVER NEAR MILTON, OREG.

This station was originally established February 15, 1903, 6 miles above the mouth of the river and 12 miles from Milton, Oreg. The gage was read once each day from the date of establishment to October 31, 1903, by N. Redden. As there were no means for making flood measurements at this point, the station was moved to the highway bridge one-fourth mile above the junction of North and South forks, 6 miles from Milton.

The channel is straight for 100 feet above and 150 feet below the bridge. The current is swift. The right bank is low, wooded, and liable to overflow. The left bank is low, but is not liable to overflow, and is without trees. The bed of the stream is composed of gravel, is free from vegetation, and is not liable to shift to any considerable extent.

Discharge measurements are made from the upstream side of the single-span highway bridge one-fourth mile above the mouth of South Fork. The initial point for soundings is the south side of a projecting beam which supports the north end of the lower chord of the bridge. The bridge has a span of 65 feet between abutments.

The gage is a vertical timber, secured to a stump on the right bank three-fourths of a mile above the highway bridge and directly back of the house of the observer, Harry Huber, who, during 1905, read the gage once each day. Bench marks were established as follows: (1) A 20-penny nail driven into a cottonwood tree 1 foot in diameter 15 feet above the gage rod; elevation, 7.00 feet. (2) A 20-penny nail driven into the tree to which the gage is attached; elevation, 7.00 feet. Elevations refer to the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of United States Geological Survey:

Description: 100, p 371; 135, pp 251-252.
Discharge: 100, p 372; 135, p 252.
Discharge, monthly: 135, p 253.
Gage heights: 100, pp 372-373; 135, pp 252-253.
Rating table: 135, p 253.

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*Discharge measurements of South Fork of Walla Walla River near Milton, Oreg., for 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| February 8 | W. C. Sawyer | 40 | 30 | 5.11 | 1.51 | 153 |
| March 18 | H. A. Yates | 47 | 49 | 3.94 | 1.67 | 193 |
| May 5 | J. H. Lewis | 45 | 56 | 4.61 | 1.78 | 270 |
| July 21 | W. C. Sawyer | 29 | 27 | 3.63 | 1.48 | 98 |
| August 12[a] | Sawyer and Lewis | 29 | 36 | 2.82 | 1.50 | 101 |
| September 14 | P. A. Cupper | 40 | 47 | 2.68 | 1.65 | 124 |
| October 16[a] | do | 35 | 46 | 2.96 | 1.65 | 136 |
| October 20[a] | do | 34 | 43 | 2.73 | 1.60 | 116 |
| November 21[a] | do | 31 | 42 | 2.73 | 1.48 | 114 |
| December 28[a] | do | 33 | 40 | 3.07 | 1.55 | 121 |

[a] Made at different section.

*Daily gage height, in feet, of South Fork of Walla Walla River near Milton, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.75 | 1.6 | 1.65 | 1.75 | 1.8 | 1.7 | 1.7 | 1.6 | 1.5 | 1.6 | 1.5 | 1.55 |
| 2 | 1.7 | 1.6 | 1.65 | 1.8 | 1.75 | 1.7 | 1.65 | 1.5 | 1.55 | 1.6 | 1.5 | 1.6 |
| 3 | 1.65 | 1.6 | 1.7 | 1.8 | 1.75 | 1.75 | 1.6 | 1.5 | 1.5 | ..... | ..... | 1.7 |
| 4 | 1.6 | 1.55 | 1.7 | 1.8 | ..... | 1.7 | 1.6 | 1.5 | 1.6 | 1.6 | ..... | 1.65 |
| 5 | 1.6 | 1.55 | 1.65 | 1.8 | 1.8 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.45 | 1.65 |
| 6 | 1.6 | 1.55 | 1.65 | 1.8 | 1.8 | 1.7 | 1.6 | 1.5 | 1.5 | ..... | 1.5 | 1.7 |
| 7 | 1.6 | 1.55 | 1.65 | 1.8 | 1.8 | 1.65 | 1.6 | 1.5 | 1.55 | 1.65 | 1.5 | 1.7 |
| 8 | 1.55 | ..... | 1.65 | ..... | 1.85 | 1.65 | 1.6 | 1.5 | 1.55 | 1.7 | 1.45 | 1.65 |
| 9 | 1.55 | ..... | 1.6 | 1.85 | 1.85 | 1.65 | 1.5 | 1.5 | 1.6 | 1.65 | 1.5 | 1.65 |
| 10 | ..... | ..... | 1.6 | 1.8 | 1.83 | ..... | 1.6 | 1.5 | 1.5 | 1.6 | 1.45 | 1.6 |
| 11 | 1.55 | 1.5 | 1.6 | 1.75 | 1.9 | 1.6 | 1.5 | 1.5 | 1.5 | 1.6 | 1.45 | 1.6 |
| 12 | 1.55 | 1.7 | 1.6 | 1.75 | 1.95 | 1.6 | 1.5 | 1.5 | 1.5 | 1.6 | 1.5 | 1.6 |
| 13 | 1.55 | 1.7 | 1 6 | 1.75 | 1.95 | 1.55 | 1.5 | 1.5 | 1.6 | 1.6 | 1.45 | 1.55 |
| 14 | 1.5 | 1.5 | 1.65 | 1.7 | 1.9 | 1.7 | 1.5 | 1.5 | 1.6 | 1.6 | 1.45 | ..... |
| 15 | 1.5 | 1.5 | ..... | 1.7 | 1.85 | 1.65 | 1.5 | 1.5 | 1.6 | 1.6 | 1.5 | 1.5 |
| 16 | 1.55 | 1.45 | 1.65 | 1.75 | 1.8 | 1.7 | 1.5 | 1.5 | 1.6 | 1.6 | 1.5 | 1.5 |
| 17 | 1.55 | 1.45 | 1.7 | 1.75 | 1.9 | 1 7 | 1.5 | 1.55 | 1.55 | 1.6 | 1.5 | 1.6 |
| 18 | 1.55 | 1.5 | 1.7 | 1.75 | 1.85 | 1.7 | 1.5 | 1.5 | 1.6 | 1.65 | 1.5 | 1.65 |
| 19 | 1.55 | 1.5 | 1.7 | 2.0 | 1.85 | 1.65 | 1.5 | 1.45 | 1.55 | 1.6 | 1.5 | 1.6 |
| 20 | 1.6 | 1.5 | 1.6 | 2.0 | 1.8 | 1.65 | 1.5 | 1.45 | 1.6 | 1.6 | 1.5 | 1.6 |
| 21 | 1.55 | 1.5 | 1.75 | 1.95 | 1.75 | 1.6 | 1.5 | 1.55 | 1.6 | 1.6 | 1.5 | 1.6 |
| 22 | 1.6 | ..... | 1.7 | 1.95 | 1.75 | 1.6 | 1.5 | 1.55 | 1.55 | ..... | 1.5 | 1.6 |
| 23 | 1.7 | 1.6 | 1.7 | 1.95 | 1.75 | 1.65 | 1.5 | 1.5 | 1.6 | 1.5 | 1,5 | 1.55 |
| 24 | 1.75 | 1.65 | 2.15 | 1.95 | ..... | 1.7 | 1.5 | 1.5 | 1.6 | 1.5 | 1.5 | 1.55 |
| 25 | 1.8 | 1.7 | 2.0 | 1.95 | ..... | 1.7 | 1.5 | 1.55 | 1.6 | 1.55 | 1.5 | ..... |
| 26 | 1.7 | 1.75 | 2.2 | 1.95 | 1.75 | 1.7 | 1.5 | 1.5 | 1.6 | 1.55 | 1.6 | ..... |
| 27 | 1.7 | ..... | 2.0 | 1.9 | 1.75 | 1.7 | 1.5 | 1.5 | 1.6 | 1.6 | 1.5 | ..... |
| 28 | 1.7 | ..... | 1.95 | 1.9 | 1.7 | 1.7 | 1.5 | 1.5 | 1.6 | ..... | 1.5 | 1.6 |
| 29 | 1.7 | ..... | 1.85 | 1.85 | 1.7 | 1.7 | 1.6 | 1.55 | 1.6 | 1.7 | 1.5 | 1.55 |
| 30 | 1.65 | ..... | 1.75 | 1.8 | 1.7 | 1.7 | 1.5 | 1.55 | 1.6 | 1.65 | ..... | 1.55 |
| 31 | 1.65 | ..... | 1.75 | ..... | 1.7 | ..... | 1.6 | 1.5 | ..... | 1.5 | ..... | 1.55 |

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*Station rating table for South Fork of Walla Walla River near Milton, Oreg., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.50 | 106 | 1.70 | 214 | 1.90 | 340 | 2.10 | 480 |
| 1.60 | 156 | 1.80 | 276 | 2.00 | 412 | 2.20 | 552 |

The above table is applicable only for open-channel conditions. It is based on six discharge measurements made during 1905. It is well defined. The table has been extended beyond these limits.

*Estimated monthly discharge of South Fork of Walla Walla River near Milton, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 276 | 106 | 167 | 10,270 |
| February | 244 | 84 | 142 | 7,856 |
| March | 552 | 156 | 239 | 14,700 |
| April | 412 | 214 | 300 | 17,850 |
| May | 378 | 214 | 277 | 17,030 |
| June | 244 | 130 | 196 | 11,660 |
| July | 214 | 106 | 127 | 7,809 |
| August | 156 | 84 | 112 | 6,887 |
| September | 156 | 106 | 141 | 8,390 |
| October | 214 | 106 | 157 | 9,654 |
| November | 156 | 84 | 103 | 6,129 |
| December | 214 | 106 | 155 | 9,531 |
| The year | 552 | 84 | 176 | 127,800 |

## WALLA WALLA RIVER ABOVE MILTON, OREG.

This station was established August 12, 1905, to replace the station at Milton, Oreg., one-half mile below. It is located near the old city reservoir, 1¼ miles above Milton. About 25 feet above the gage there is a curve in the low-water channel, but in high water it is nearly straight. Below, the channel is straight for about 400 feet. There are riffles a short distance above and below the cable. The channel is composed of coarse gravel and cobbles and may shift to some extent. Both banks are low, but seldom overflow beyond the limit of the cable.

Discharge measurements are made by means of a cable and car. The initial point for soundings is the zero of the tagged wire on the right bank.

The gage is a vertical staff on the right bank, 24 feet above the cable. During 1905 the gage was read once each day by L. Martin. The bench mark is a spike under the corner of the roof of the old reservoir; elevation, 9.71 feet above the datum of the gage.

*Discharge measurements of Walla Walla River above Milton, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 12 | Lewis and Sawyer | 42 | 48 | 2.13 | 3.83 | 103 |
| September 6 | W. C. Sawyer | 43 | 47 | 2.22 | 3.85 | 104 |
| October 6 | P. A. Cupper | 43 | 54 | 2.47 | 3.95 | 133 |
| October 21 | do | 44 | 55 | 2.36 | 3.95 | 129 |
| November 21 | do | 43 | 53 | 2.52 | 3.98 | 132 |
| December 28 | do | 42 | 62 | 2.78 | 4.05 | 172 |

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*Daily gage height, in feet, of Walla Walla River above Milton, Oreg., for 1905.*

| Day. | Aug. | Sept. | Oct. | Nov. | Dec. | Day. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 3.88 | 3.92 | 4.0 | 4.02 | 17 | 3.88 | 3.9 | 3.98 | 3.95 | 4.15 |
| 2 | ..... | 3.82 | 3.92 | 4.0 | 4.1 | 18 | 3.85 | 3.9 | 3.98 | 3.98 | 4.18 |
| 3 | ..... | 3.82 | 3.9 | 3.98 | 4.22 | 19 | 3.88 | 3.9 | 3.98 | 4.0 | 4.2 |
| 4 | ..... | 3.85 | 3.9 | 4.0 | 4.25 | 20 | 3.85 | 3.9 | 3.98 | 4.0 | 4.15 |
| 5 | ..... | 3.85 | 3.92 | 3.98 | 4.22 | 21 | 3.88 | 3.9 | 3.9 | 3.98 | 4.15 |
| 6 | ..... | 3.85 | 3.98 | 3.98 | 4.2 | 22 | 3.88 | 3.88 | 3.95 | 3.98 | 4.12 |
| 7 | ..... | 3.85 | 4.0 | 3.98 | 4.2 | 23 | 3.85 | 3.88 | 3.98 | 3.95 | 4.10 |
| 8 | ..... | 3.85 | 4.0 | 3.95 | 4.2 | 24 | 3.85 | 3.88 | 4.0 | 3.95 | 4.08 |
| 9 | ..... | 3.85 | 3.98 | 3.95 | 4.18 | 25 | 3.88 | 3.88 | 4.05 | 3.95 | 4.08 |
| 10 | ..... | 3.82 | 3.95 | 4.0 | 4.12 | 26 | 3.88 | 3.9 | 4.1 | 4.12 | 4.08 |
| 11 | ..... | 3.85 | 3.95 | 3.98 | 4.12 | 27 | 3.88 | 3.95 | 4.0 | 4.12 | 4.08 |
| 12 | 3.82 | 3.88 | 3.92 | 3.96 | 4.08 | 28 | 3.85 | 3.98 | 4.0 | 4.08 | 4.05 |
| 13 | 3.85 | 3.9 | 3.9 | 3.95 | 4.05 | 29 | 3.88 | 3.92 | 3.98 | 4.02 | 4.05 |
| 14 | 3.88 | 3.9 | 3.9 | 3.95 | 4.02 | 30 | 3.88 | 3.92 | 4.0 | 4.05 | 4.05 |
| 15 | 3.88 | 3.9 | 3.98 | 3.95 | 4.02 | 31 | 3.9 | ..... | 4.0 | ..... | 4.05 |
| 16 | 3.9 | 3.9 | 3.95 | 3.92 | 4.02 | | | | | | |

*Station rating table for Walla Walla River above Milton, Oreg., from August 12 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 3.80 | 94 | 4.00 | 147 | 4.20 | 207 |
| 3.90 | 120 | 4.10 | 175 | 4.30 | 240 |

The above table is applicable only for open-channel conditions. It is based on six discharge measurements made during 1905. It is well defined to gage height 4 feet.

*Estimated monthly discharge of Walla Walla River above Milton, Oreg., for 1905.*

| Month | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| August 12-31 | 120 | 99 | 112 | 4,442 |
| September | 142 | 99 | 115 | 6,843 |
| October | 175 | 120 | 138 | 8,485 |
| November | 181 | 125 | 144 | 8,569 |
| December | 224 | 153 | 181 | 11,130 |

## WALLA WALLA RIVER AT MILTON, OREG.

This station was established February 14, 1903, by T. A. Noble. Owing to the influence of a diversion dam just below the station was abandoned September 30, 1905, the station 1¼ miles above Milton taking its place.

The channel is straight for 80 feet above and 150 feet below the station. The current is swift. Both banks are low, wooded, but not liable to overflow. There is but one channel at all stages. The bed of the stream is composed of gravel, is free from vegetation, and is liable to shift.

During 1903 discharge measurements were made from a cable. Measurements made at this point include the discharge of the irrigation ditch just below the gage. At the close

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of the season of 1903 the cable was abandoned and discharge measurements have since been made from the highway bridge. Measurements made at this point do not include the discharge of the irrigation ditch just below the gage. The ditch has to be measured separately, but its discharge is included in the estimate given below. Another irrigation ditch is taken out on the left bank just below the bridge; this is included in the measurements made at the bridge. The initial point for soundings is the end of the lower chord on the upstream side of the bridge, at the right bank. The bridge has a single span of 75 feet between abutments.

The gage is a vertical rod on the left bank one-half mile above the county bridge and just above the head gate of an irrigation ditch. During 1905 the gage was read once each day by S. L. Smith. The bench mark is the top of a sharp projecting rock, 4 feet from the gage and 3 feet from the tree to which the gage is attached; elevation, 4.37 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 368; 135, p 254.
Discharge: 100, p 369; 135, p 254.
Discharge, monthly: 100, p 370; 155, p 256.
Gage heights: 100, pp 369–370; 135, p 255.
Rating table: 100, p 370; 135, p 255.

*Discharge measurements of Walla Walla River at Milton, Oreg., in 1905.*

| Date. | Hydrographer. | Gage height. | Discharge. | Remarks. |
|---|---|---|---|---|
| | | *Feet.* | *Second-feet.* | |
| February 8 | W. C. Sawyer | 1.71 | 190 | 78 second-feet in ditch included. |
| March 18 | H. A. Yates | 1.85 | 240 | 64 second-feet in ditch included. |
| May 5 | J. H. Lewis | 1.75 | 378 | 77 second-feet in ditch included. |
| July 21 | W. C. Sawyer | 1.64 | 98 | 52 second-feet in ditch included. |
| August 11 | Sawyer and Lewis | 1.42 | 90 | Do. |
| September 1 | Sawyer and Cupper | 1.37 | 95 | 53 second-feet in ditch included. |

*Daily gage height, in feet, of Walla Walla River at Milton, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.74 | 1.54 | 1.81 | 1.7 | 1.65 | 1.55 | 1.94 | 1.48 | 1.4 |
| 2 | 1.69 | 1.51 | 1.8 | 1.78 | 1.62 | 1.55 | 1.88 | 1.46 | 1.39 |
| 3 | 1.56 | 1.52 | 1.8 | 1.76 | 1.7 | 2.11 | 1.88 | 1.45 | 1.4 |
| 4 | 1.56 | 1.74 | 1.8 | 1.75 | 1.72 | 2.06 | 1.86 | 1.44 | 1.41 |
| 5 | 1.56 | 1.74 | 1.79 | 1.74 | 1.72 | 2.03 | 1.84 | 1.43 | 1.41 |
| 6 | 1.53 | 1.72 | 1.78 | 1.73 | 1.72 | 2.0 | 1.82 | 1.4 | 1.41 |
| 7 | 1.48 | 1.72 | 1.76 | 1.75 | 1.67 | 1.97 | 1.78 | 1.36 | 1.41 |
| 8 | 1.45 | 1.71 | 1.75 | 1.78 | 1.66 | 1.95 | 1.68 | 1.36 | 1.4 |
| 9 | 1.48 | 1.71 | 1.74 | 1.78 | 1.86 | 1.92 | 1.58 | 1.36 | 1.4 |
| 10 | 1.5 | 1.71 | 1.78 | 1.8 | 1.92 | 1.9 | 1.5 | 1.36 | 1.41 |
| 11 | 1.51 | 1.68 | 1.81 | 1.74 | 2.02 | 1.82 | 1.5 | 1.37 | 1.42 |
| 12 | 1.52 | 1.66 | 1.82 | 1.67 | 1.99 | 1.78 | 1.73 | 1.37 | 1.43 |
| 13 | 1.51 | 1.64 | 1.84 | 1.68 | 1.93 | 1.74 | 1.7 | 1.36 | 1.45 |
| 14 | 1.49 | 1.62 | 1.84 | 1.69 | 1.85 | 1.72 | 1.7 | 1.37 | 1.46 |
| 15 | 1.5 | 1.61 | 1.84 | 1.66 | 1.8 | 1.7 | 1.66 | 1.38 | 1.46 |
| 16 | 1.51 | 1.61 | 1.83 | 1.66 | 1.75 | 1.7 | 1.65 | 1.4 | 1.45 |
| 17 | 1.5 | 1.7 | 1.84 | 1.64 | 1.73 | 1.72 | 1.63 | 1.46 | 1.45 |
| 18 | 1.51 | 1.74 | 1.84 | 1.66 | 1.71 | 1.64 | 1.62 | 1.44 | 1.45 |
| 19 | 1.49 | 1.8 | 1.84 | 1.66 | 1.68 | 1.57 | 1.6 | 1.43 | 1.45 |
| 20 | 1.53 | 1.79 | 1.84 | 1.7 | 1.64 | 1.64 | 1.62 | 1.42 | 1.46 |
| 21 | 1.51 | 1.76 | 1.95 | 1.8 | 1.62 | 1.64 | 1.64 | 1.43 | 1.46 |

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*Daily gage height, in feet, of Walla Walla River at Milton, Oreg., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 22 | 1.51 | 1.72 | 1.98 | 1.94 | 1.6 | 1.8 | 1.63 | 1.43 | 1.46 |
| 23 | 1.59 | 1.8 | 1.95 | 1.88 | 1.59 | 1.85 | 1.62 | 1.43 | 1.46 |
| 24 | 1.76 | 1.88 | 2.13 | 1.91 | 1.63 | 2.06 | 1.61 | 1.42 | 1.47 |
| 25 | 1.8 | 1.97 | 2.01 | 1.95 | 1.65 | 2.12 | 1.58 | 1.42 | 1.47 |
| 26 | 1.76 | 1.87 | 2.12 | 1.91 | 1.65 | 2.1 | 1.45 | 1.41 | 1.48 |
| 27 | 1.73 | 1.84 | 2.05 | 1.88 | 1.65 | 2.06 | 1.49 | 1.41 | 1.6 |
| 28 | 1.71 | 1.82 | 1.91 | 1.85 | 1.64 | 2.04 | 1.5 | 1.41 | 1.6 |
| 29 | 1.68 | ..... | 1.81 | 1.7 | 1.62 | 2.02 | 1.5 | 1.42 | 1.56 |
| 30 | 1.66 | ..... | 1.81 | 1.69 | 1.6 | 1.95 | 1.48 | 1.42 | 1.56 |
| 31 | 1.6 | ..... | 1.72 | ..... | 1.58 | ..... | 1.46 | 1.41 | ..... |

*Estimated monthly discharge of Walla Walla River at Milton, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 280 | 150 | 194 | 11,930 |
| February | 305 | 150 | 200 | 11,110 |
| March | 410 | 200 | 260 | 15,990 |
| April | 540 | 245 | 369 | 21,950 |
| May | 610 | 275 | 363 | 22,320 |
| June | 280 | 170 | 216 | 12,850 |
| July | 225 | 100 | 129 | 7,932 |
| August | 145 | 97 | 103 | 6,333 |
| September | 114 | 100 | 104 | 6,188 |
| The period | | | | 116,600 |

NOTE.—Owing to changeable conditions at this station during 1905 no rating table can be published and the monthly estimates, which are based on a series of curves, each covering a short period, are only approximate.

## UMATILLA RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Umatilla River rises in the well-wooded country of northeastern Oregon and flows in a general westerly direction, entering Columbia River below the mouth of Walla Walla River. The country north of the Umatilla is high and rolling. A number of canals divert water from the lower course of the stream to irrigate lands on either side.

### UMATILLA RIVER AT GIBBON, OREG.

This station was established by C. C. Babb July 22, 1896.

The channel is straight for 100 feet above and below the station. The right bank is high. The left bank is rather low and has a slough during high water. The bed of the stream is composed of gravel and is somewhat shifting.

Discharge measurements are made by means of a cable and car. The initial point for soundings is the face of the tree on the right bank, to which the cable is attached.

Several gages were used from time to time, owing to the varying conditions. October 15, 1904, a vertical staff gage was fastened to a point of rocks in a pool where the bed is least liable to shift on the north side of the river about one-half mile below the railroad station at Bingham Springs and one-half mile above the cable from which discharge measurements are made. No relation has been established between this and previous gages. During 1905 the gage was read once each day by Walter Swart. The bench mark is a square chisel draft and the letters "B. M." cut in the rock about 15 feet from the gage, 10 feet downstream; elevation, 5.17 feet above the datum of the gage.

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Information in regard to this station is contained in the following publications of the United States Geological Survey (Ann=Annual Report; WS=Water-Supply Paper):

Description: Ann 18, iv, p 361; 19, iv, p 493; WS 16, p 180; 28, p 159; 38, pp 376–377; 51, p 444; 66, p 135; 85, pp 183–184; 100, pp 366–367; 135, pp 256–257.
Discharge: Ann 18, iv, p 361; WS 16, p 180; 28, p 169; 85, p 184; 100, p 367; 135, p 257.
Discharge, monthly: Ann 19, iv, p 494; 20, iv, p 515; 21, iv, p 430; 22, iv, p 453; WS 75, p 206; 85, p 185.
Discharge, yearly: Ann 20, iv, p 63.
Gage heights: WS 11, p 88; 16, p 180; 28, p 167; 38, p 377; 51, p 445; 66, p 137; 85, p 184; 100, pp 367–368; 135, pp 257–258.
Hydrographs: Ann 19, iv, p 494; 20, iv, p 515; 21, iv, p 430; 22, iv, p 453.
Rating tables: Ann 19, iv, p 493; WS 28, p 170; 39, p 454; 52, p 522; 66, p 177; 85, p 185.

*Discharge measurements of Umatilla River at Gibbon, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| March 3 | J. H. Lewis | 100 | 85 | 6.36 | 2.00 | 540 |
| March 10 | W. C. Sawyer | 53 | 69 | 5.93 | 1.75 | 410 |
| March 28 | J. H. Lewis | 106 | 143 | 6.85 | 2.50 | 979 |
| April 7 | W. C. Sawyer | 110 | 167 | 6.57 | 2.65 | 1,094 |
| May 6 | do | 101 | 102 | 6.43 | 2.10 | 660 |
| August 5 [a] | do | 34 | 41 | 1.41 | 1.10 | 58 |
| August 26 | do | 34 | 38 | 1.39 | 1.10 | 53 |
| October 19 [a] | Sawyer and Hall | 37 | 49 | 1.73 | 1.22 | 85 |
| December 2 [a] | R. S. Hall | 48 | 63 | 2.53 | 1.39 | 160 |

[a] Made at different section.

*Daily gage height, in feet, of Umatilla River at Gibbon, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1.6 | 2.0 | 2.3 | 1.8 | 1.55 | 1.3 | 1.1 | 1.1 | 1.25 | 1.2 | 1.35 |
| 2 | 1.5 | 1.5 | 2.0 | 2.4 | 1.9 | 1.7 | 1.3 | 1.1 | 1.1 | 1.2 | 1.2 | 1.4 |
| 3 | 1.5 | 1.5 | 2.0 | ..... | 2.0 | 1.65 | 1.3 | 1.1 | 1.1 | 1.15 | 1.2 | 1.52 |
| 4 | 1.4 | 1.5 | 1.9 | 2.5 | 2.0 | ..... | 1.3 | 1.1 | 1.1 | 1.15 | 1.2 | 1.65 |
| 5 | 1.4 | 1.5 | 1.9 | 2.8 | 2.0 | 1.6 | 1.3 | 1.1 | 1.1 | 1.2 | 1.2 | 1.62 |
| 6 | 1.4 | 1.5 | 1.9 | 2.8 | 2.1 | 1.6 | 1.3 | 1.1 | 1.1 | 1.2 | 1.2 | 1.6 |
| 7 | 1.4 | 1.5 | 1.8 | 2.65 | ..... | 1.6 | 1.25 | 1.1 | 1.1 | 1.2 | 1.2 | 1.6 |
| 8 | 1.4 | 1.5 | 1.8 | 2.5 | ..... | 1.55 | 1.25 | 1.1 | 1.1 | 1.2 | 1.2 | 1.6 |
| 9 | 1.4 | 1.5 | 1.75 | 2.5 | 2.1 | 1.5 | 1.25 | 1.1 | 1.1 | 1.2 | 1.2 | 1.6 |
| 10 | 1.4 | 1.5 | 1.75 | 2.3 | 2.1 | 1.5 | 1.25 | 1.1 | 1.1 | 1.2 | 1.2 | 1.6 |
| 11 | 1.4 | 1.5 | 1.7 | 2.1 | 2.25 | 1.45 | 1.2 | 1.1 | 1.1 | 1.2 | 1.2 | 1.4 |
| 12 | 1.4 | 1.5 | 1.7 | 2.2 | 2.2 | 1.4 | 1.2 | 1.1 | 1.1 | 1.2 | 1.2 | 1.4 |
| 13 | 1.3 | 1.5 | 1.8 | 2.1 | 2.1 | 1.4 | 1.15 | 1.1 | 1.1 | 1.2 | 1.2 | 1.4 |
| 14 | 1.3 | 1.5 | 1.8 | 2.0 | 2.0 | 1.35 | 1.15 | 1.1 | 1.1 | 1.2 | 1.2 | 1.4 |
| 15 | 1.3 | 1.5 | 1.8 | 2.0 | 1.95 | 1.35 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.4 |
| 16 | 1.3 | 1.5 | 1.8 | 2.0 | 1.9 | 1.35 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.4 |
| 17 | 1.3 | 1.4 | 1.8 | 1.95 | 1.85 | 1.3 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.5 |
| 18 | 1.3 | 1.4 | 1.8 | 1.9 | 1.8 | 1.3 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.55 |
| 19 | 1.3 | 1.4 | 1.8 | 2.0 | 1.8 | 1.3 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.55 |
| 20 | 1.3 | 1.4 | 1.8 | 2.1 | 1.8 | 1.25 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.55 |
| 21 | 1.3 | 1.4 | 2.0 | 2.2 | 1.7 | 1.25 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.6 |
| 22 | 1.3 | 1.4 | ..... | 2.3 | 1.5 | 1.25 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.6 |
| 23 | 1.6 | 1.5 | 2.0 | 2.3 | 1.7 | 1.25 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.55 |
| 24 | 2.0 | 1.6 | 2.4 | 2.2 | 1.85 | 1.3 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.5 |
| 25 | 2.2 | 2.0 | 2.2 | 2.1 | 1.9 | ..... | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | ..... |

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*Daily gage height, in feet, of Umatilla River at Gibbon, Oreg., for 1905* —Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 2.0 | 2.0 | ..... | 2.0 | 1.8 | 1.35 | 1.1 | ..... | 1.1 | 1.2 | 1.3 | 1.45 |
| 7 | ..... | 2.0 | 2.6 | 1.9 | 1.8 | 1.4 | 1.1 | 1.1 | 1.1 | 1.2 | 1.3 | 1.4 |
| 8 | 1.9 | 2.0 | 2.45 | 1.8 | 1.75 | 1.35 | 1.1 | 1.1 | 1.1 | 1.2 | 1.3 | 1.4 |
| 9 | 1.8 | ..... | 2.35 | 1.7 | 1.7 | 1.35 | 1.1 | 1.1 | 1.3 | 1.2 | 1.3 | 1.4 |
| 10 | 1.8 | ..... | 2.3 | 1.7 | 1.65 | 1.35 | 1.1 | 1.1 | 1.3 | 1.2 | 1.35 | 1.4 |
| 11 | 1.8 | ..... | 2.2 | ..... | 1.6 | ..... | 1.1 | 1.1 | ..... | 1.2 | ..... | 1.4 |

NOTE.—Ice conditions during part of February.

*Station rating table for Umatilla River at Gibbon, Oreg., from October 15, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.00 | 32 | 1.60 | 282 | 2.10 | 638 | 2.60 | 1,060 |
| 1.10 | 56 | 1.70 | 346 | 2.20 | 718 | 2.70 | 1,150 |
| 1.20 | 82 | 1.80 | 414 | 2.30 | 800 | 2.80 | 1,240 |
| 1.30 | 120 | 1.90 | 486 | 2.40 | 885 | 2.90 | 1,330 |
| 1.40 | 168 | 2.00 | 560 | 2.50 | 970 | 3.00 | 1,420 |
| 1.50 | 222 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on 9 discharge measurements made during 1905. It is well defined.

*Estimated monthly discharge of Umatilla River at Gibbon, Oreg., for 1904 and 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| 1904. | | | | |
| October 15–31 | 90 | 56 | 78.4 | 2,644 |
| November | 120 | 56 | 78.9 | 4,695 |
| December | 346 | 82 | 117 | 7,194 |
| 1905. | | | | |
| January | 718 | 120 | 250 | 15,370 |
| February | 560 | 168 | 263 | 14,610 |
| March | 1,060 | 346 | 554 | 34,060 |
| April | 1,240 | 346 | 721 | 42,900 |
| May | 759 | 222 | 489 | 30,070 |
| June | 346 | 101 | 182 | 10,830 |
| July | 120 | 56 | 76.7 | 4,716 |
| August | 56 | 56 | 56.0 | 3,443 |
| September | 120 | 56 | 60.3 | 3,588 |
| October | 101 | 69 | 81.8 | 5,030 |
| November | 144 | 82 | 89.1 | 5,302 |
| December | 314 | 144 | 220 | 13,530 |
| The year | 1,240 | 56 | 254 | 183,400 |

NOTE.—Discharge interpolated for missing gage heights.

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## UMATILLA RIVER AT PENDLETON, OREG.

This station was established May 22, 1903, by F. W. Huber and discontinued June 11, 1905. It is located at the Main Street Bridge at Pendleton, Oreg.

The channel is straight for 250 feet above and 200 feet below the railroad bridge from which discharge measurements are made. The current is swift at this point, but has a lower velocity than at the bridge at which the gage is located. The right bank is low and will overflow under the trestle on this bank. The left bank is high and is partly riprap. At low stages there will be some backwater at the south bank. There is but one channel at all stages. The bed of the stream is composed of gravel and is shifting.

Discharge measurements are made from the Oregon Railroad and Navigation Company's bridge, about 1 mile downstream from the Main Street Bridge. The initial point for soundings is the face of the crib abutment on the left bank. The railroad bridge consists of a single span of 145 feet, with 116 feet of trestle approach on the right bank and 34 feet on the left bank.

The gage is a vertical staff fastened to the middle of the left (south) side of the center pier of the Main Street Bridge. During 1905 the gage was read by the staff of the Geological Survey office at Pendleton. The bench mark is the top of the south side of the steel caisson at the east end of the middle pier of the Main Street Bridge; elevation, 16.50 feet above the datum of the gage.

The flour-mill ditch (Byer's) takes 100 second-feet or less of water about 1½ miles above the gage and returns it to the river about 200 feet above the gage, so that it interferes with the measurements in no way except for a time during very low water, when the water is drawn down and then restored. The gage was read only when the flow was normal.

A short distance above the bridge at which the gage is located water is taken out of the river by the Farmers' mill ditch. The water is returned to the river at a point about 1,500 feet above the railroad bridge. The Farmers' mill ditch does not affect the reading of the gage when above 4 feet. For low stages of the river the amount of water in the ditch should be taken out from the measured discharge in making a curve and rating table, and should then be added to the discharge taken from the table. June 15, 1904, a gage was placed on the Farmers' mill ditch and read from that time until the station was abandoned.

Information in regard to this station is contained in the following publications of the United States Geological Survey (Bull=Bulletin; WS=Water-Supply Paper):

Description: Bull 131, p 68; WS 100, pp 362–363; 135, pp 258–259.
Discharge: Bull 131, pp 69, 90; WS 100, p 364; 135, p 259.
Discharge, monthly: Bull 131, p 69.
Gage heights: WS 100, p 364; 135, p 260.

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*Discharge measurements of Umatilla River at Pendleton, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. | Remarks. |
|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* | |
| January 28 | Williams and Yates. | 90 | 294 | 2.24 | 4.60 | 657 | 128 second-feet in ditch included. |
| February 24 | Lewis and Yates | 83 | 211 | 1.30 | 4.19 | 275 | 58 second-feet in ditch included. |
| February 27 | W. C. Sawyer | 92 | 269 | 2.29 | 4.58 | 615 | 120 second-feet in ditch included. |
| March 24 | H. S. Williams | 100 | 318 | 2.98 | 4.99 | 941 | 240 second-feet in ditch included. |
| March 28 | Lewis and Yates | 100 | 352 | 3.69 | 5.20 | 1,302 | 166 second-feet in ditch included. |
| June 8 | W. C. Sawyer | 80 | 207 | 1.35 | 4.26 | 280 | 29 second-feet in ditch included. |
| June 26 | Sawyer and King | 80 | 194 | .84 | 4.17 | 162 | Ditch dry. |
| August 28[a] | Sawyer and Landes. | 16 | 16.6 | 2.22 | ..... | 36.9 | |
| September 9[a] | W. C. Sawyer | 27 | 22.8 | 1.79 | ..... | 40.4 | |
| October 19[a] | do | 45 | 52 | 1.37 | ..... | 72 | |
| November 15[a] | R. S. Hall | 45 | 52 | 1.43 | ..... | 79 | |
| November 17 | do | 76 | 90 | .29 | ..... | 56 | |
| November 17 | do | 76 | 90 | .33 | ..... | 63 | |
| December 7 | do | 73 | 248 | 1.07 | ..... | 264 | |
| December 7 | do | 73 | 248 | 1.10 | ..... | 273 | |
| December 26 | do | 73 | 242 | .98 | ..... | 237 | |

[a] Measurements made above head of Byer's mill ditch.

*Daily gage height, in feet, of Umatilla River at Pendleton, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | Day. | Jan. | Feb. | Mar. | Apr. | May. | June. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.05 | 4.35 | 4.52 | 4.99 | 4.5 | 4.45 | 17 | 3.87 | 4.03 | 4.38 | 4.65 | ..... | ..... |
| 2 | 4.0 | 4.28 | 4.5 | 5.21 | 4.45 | 4.4 | 18 | 3.88 | 4.02 | 4.38 | 4.65 | 4.55 | ..... |
| 3 | 4.0 | 4.23 | 4.52 | 5.25 | 4.5 | 4.37 | 19 | 3.88 | 4.0 | 4.38 | 4.63 | 4.5 | ..... |
| 4 | 3.98 | 4.19 | 4.52 | 5.15 | 4.6 | 4.35 | 20 | 3.88 | 4.02 | 4.39 | 4.77 | 4.45 | ..... |
| 5 | 3.97 | 4.14 | 4.52 | 5.22 | 4.7 | 4.33 | 21 | 3.9 | 4.02 | 4.48 | 4.80 | 4.45 | ..... |
| 6 | 3.95 | 4.11 | 4.5 | 5.3 | 4.73 | 4.3 | 22 | ..... | 4.07 | 4.58 | 4.80 | 4.4 | ..... |
| 7 | 3.92 | 4.1 | 4.49 | 5.25 | 4.72 | 4.28 | 23 | 4.0 | 4.1 | 4.62 | 4.85 | 4.42 | ..... |
| 8 | 3.9 | 4.09 | 4.42 | 5.15 | 4.67 | 4.26 | 24 | 4.48 | 4.19 | 5.0 | 4.82 | 4.5 | ..... |
| 9 | 3.9 | 4.08 | 4.38 | 5.05 | 4.8 | 4.24 | 25 | 4.78 | 4.39 | 4.98 | 4.78 | 4.55 | ..... |
| 10 | 3.9 | 4.08 | 4.35 | 4.95 | 4.78 | 4.2 | 26 | 4.61 | 4.56 | 5.33 | 4.75 | 4.52 | ..... |
| 11 | 3.9 | 4.1 | 4.38 | 4.85 | 4.82 | 4.18 | 27 | 4.6 | 4.58 | 5.45 | 4.66 | 4.55 | ..... |
| 12 | 3.9 | 4.0 | 4.37 | 4.83 | 4.85 | ..... | 28 | 4.61 | 4.5 | 5.3 | 4.6 | 4.5 | ..... |
| 13 | 3.8 | 4.1 | 4.32 | 4.78 | 4.8 | ..... | 29 | 4.59 | ..... | 5.12 | 4.55 | 4.5 | ..... |
| 14 | 3.8 | 4.05 | 4.4 | 4.75 | 4.75 | ..... | 30 | 4.5 | ..... | 5.05 | 4.52 | 4.45 | ..... |
| 15 | 3.86 | 4.0 | 4.4 | 4.65 | 4.68 | ..... | 31 | 4.41 | ..... | ..... | ..... | 4.45 | ..... |
| 16 | 3.84 | 4.0 | 4.38 | 4.65 | 4.65 | ..... | | | | | | | |

## UMATILLA RIVER AT YOAKUM, OREG.

This station was established May 5, 1903, by N. S. Dils. It is located one-half mile east of Yoakum, a station of the Oregon Railroad and Navigation Company, at what is known as the Yoakum wagon bridge.

The channel is straight for 1,000 feet above and below the station. The current is swift and has a well-distributed velocity. Both banks are high and are composed of gravel. The right bank will not overflow. The left bank will overflow only at extreme flood stages.



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The bed of the stream is composed of gravel and is permanent. There is but one channel at all stages.

Discharge measurements are made from the single-span wagon bridge. The initial point for soundings is the end of the lower chord of the upstream side on the left bank.

The gage is a vertical staff attached to the right abutment of the bridge. During 1905 readings have been made once each day by Luther Dehaven. The bench mark is a 60-penny nail and two 8-penny nails driven side by side into the second timber from the top of the left abutment, downstream side; elevation, 13.00 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, pp 360–361; 135, pp 260–261.
Discharge: 100, p 361; 135, p 261.
Discharge, monthly: 100, p 362; 135, p 263.
Gage heights: 100, p 361; 135, pp 261–262.
Rating table: 100, p 362; 135, p 262.

*Discharge measurements of Umatilla River at Yoakum, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| February 25 | J. H. Lewis | 76 | 209 | 2.12 | 4.28 | 444 |
| March 24 | Lewis and Yates | 76 | 296 | 3.99 | 5.48 | 1,180 |
| May 8 | W. C. Sawyer | 76 | 273 | 3.14 | 4.93 | 856 |
| June 30 | do | 76 | 129 | 1.36 | 3.37 | 175 |
| August 18[a] | do | 49 | 30 | .80 | 2.66 | 24 |
| September 1 | F. C. Dillard | 73 | 96 | .55 | 2.98 | 54 |
| October 1[a] | W. C. Sawyer | 60 | 47 | 1.28 | 3.00 | 60 |
| October 21 | Sawyer and Hall | 74 | 120 | .61 | 3.12 | 74 |
| December 12 | R. S. Hall | 76 | 188 | 1.52 | 3.96 | 287 |

[a] Measurements made at different section.

*Daily gage height, in feet, of Umatilla River at Yoakum, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.0 | 4.3 | 4.5 | 5.5 | 4.4 | 4.1 | 3.3 | 2.6 | 2.7 | 3.0 | 3.3 | 3.4 |
| 2 | 4.0 | 4.2 | 4.6 | 6.1 | 4.3 | 4.1 | 3.1 | 2.6 | 2.7 | 3.0 | 3.3 | 3.5 |
| 3 | 3.9 | 4.1 | 4.6 | 6.0 | 4.4 | 4.1 | 3.1 | 2.6 | 2.7 | 3.0 | 3.3 | 3.6 |
| 4 | 3.9 | 4.0 | 4.6 | 6.0 | 4.7 | 4.1 | 3.1 | 2.6 | 2.7 | 3.0 | 3.3 | 4.1 |
| 5 | 3.9 | 4.0 | 4.6 | 6.0 | 5.0 | 4.1 | 3.1 | 2.6 | 2.7 | 3.0 | 3.3 | 4.1 |
| 6 | 3.9 | 3.9 | 4.6 | 6.0 | 5.0 | 4.1 | 3.0 | 2.6 | 2.7 | 3.1 | 3.3 | 4.1 |
| 7 | 3.9 | 3.9 | 4.6 | 6.0 | 5.0 | 4.1 | 3.0 | 2.6 | 2.7 | 3.2 | 3.3 | 4.1 |
| 8 | 3.8 | 3.8 | 4.5 | 6.0 | 4.9 | 3.9 | 3.0 | 2.6 | 2.7 | 3.2 | 3.3 | 4.3 |
| 9 | 3.7 | 3.8 | 4.4 | 5.7 | 5.2 | 3.9 | 3.0 | 2.6 | 2.75 | 3.2 | 3.3 | 4.3 |
| 10 | 3.7 | 3.7 | 4.4 | 5.6 | 5.2 | 3.9 | 3.0 | 2.6 | 2.75 | 3.1 | 3.2 | 4.3 |
| 11 | 3.7 | 3.6 | 4.4 | 5.4 | 5.2 | 3.8 | 3.0 | 2.6 | 2.75 | 3.1 | 3.2 | 4.2 |
| 12 | 3.7 | 3.5 | 4.4 | 5.2 | 5.3 | 3.7 | 3.0 | 2.6 | 3.12 | 3.1 | 3.2 | 4.0 |
| 13 | 3.6 | 3.5 | 4.4 | 5.1 | 5.2 | 3.7 | 3.0 | 2.6 | 3.5 | 3.1 | 3.2 | 4.0 |
| 14 | 3.5 | 3.5 | 4.4 | 5.0 | 5.0 | 3.6 | 3.0 | 2.6 | 2.8 | 3.1 | 3.2 | 3.9 |
| 15 | 3.5 | 3.5 | 4.4 | 4.9 | 4.9 | 3.5 | 3.0 | 2.6 | 2.9 | 3.3 | 3.2 | 3.9 |
| 16 | 3.5 | 3.5 | 4.4 | 4.9 | 4.7 | 3.4 | 3.0 | 2.6 | 2.9 | 3.3 | 3.2 | 3.8 |
| 17 | 3.5 | 3.5 | 4.4 | 4.8 | 4.7 | 3.4 | 3.0 | 2.7 | 2.9 | 3.3 | 3.2 | 3.8 |
| 18 | 3.5 | 3.5 | 4.4 | 4.9 | 4.6 | 3.4 | 2.9 | 2.7 | 2.9 | 3.2 | 3.2 | 4.0 |
| 19 | 3.5 | 3.9 | 4.4 | 5.0 | 4.5 | 3.3 | 2.9 | 2.7 | 2.9 | 3.1 | 3.3 | 4.1 |
| 20 | 3.6 | 3.7 | 4.4 | 5.0 | 4.4 | 3.2 | 2.9 | 2.7 | 2.9 | 3.1 | 3.3 | 4.1 |

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*Daily gage height, in feet, of Umatilla River at Yoakum, Oreg., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.6 | 3.6 | 4.5 | 5.0 | 4.4 | 3.2 | 2.9 | 2.7 | 2.9 | 3.1 | 3.3 | 4.1 |
| 2 | 3.7 | 3.5 | 4.7 | 5.0 | 4.3 | 3.2 | 2.9 | 2.7 | 2.9 | 3.1 | 3.3 | 4.1 |
| 3 | 3.8 | 3.6 | 4.8 | 5.0 | 4.3 | 4.0 | 2.8 | 2.7 | 2.9 | 3.1 | 3.3 | 4.1 |
| 4 | 4.3 | 4.0 | 5.4 | 5.0 | 4.4 | 3.6 | 2.8 | 2.7 | 2.9 | 3.1 | 3.3 | 4.1 |
| 5 | 4.8 | 4.3 | 5.5 | 5.0 | 4.4 | 3.5 | 2.7 | 2.7 | 2.9 | 3.1 | 3.3 | 4.5 |
| 6 | 4.8 | 4.4 | 5.9 | 4.9 | 4.4 | 3.4 | 2.7 | 2.7 | 3.1 | 3.1 | 3.3 | 4.5 |
| 7 | 4.7 | 4.4 | 6.2 | 4.6 | 4.3 | 3.4 | 2.7 | 2.7 | 3.2 | 3.1 | 3.3 | 4.4 |
| 8 | 4.7 | 4.4 | 6.0 | 4.6 | 4.3 | 3.4 | 2.6 | 2.7 | 3.0 | 3.2 | 3.3 | 4.5 |
| 9 | 4.5 | ..... | 5.8 | 4.5 | 4.2 | 3.4 | 2.6 | 2.7 | 3.0 | 3.2 | 3.4 | 4.5 |
| 10 | 4.4 | ..... | 5.5 | 4.4 | 4.2 | 3.2 | 2.6 | 2.7 | 3.0 | 3.2 | 3.4 | 4.3 |
| 11 | 4.3 | ..... | 5.5 | ..... | 4.1 | ..... | 2.6 | 2.7 | ..... | 3.2 | ..... | 4.3 |

*Station rating table for Umatilla River at Yoakum, Oreg., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.60 | 20 | 3.60 | 182 | 4.50 | 565 | 5.40 | 1,270 |
| 2.70 | 28 | 3.70 | 210 | 4.60 | 630 | 5.50 | 1,360 |
| 2.80 | 37 | 3.80 | 240 | 4.70 | 700 | 5.60 | 1,455 |
| 2.90 | 47 | 3.90 | 275 | 4.80 | 770 | 5.70 | 1,550 |
| 3.00 | 59 | 4.00 | 315 | 4.90 | 845 | 5.80 | 1,645 |
| 3.10 | 73 | 4.10 | 355 | 5.00 | 925 | 5.90 | 1,740 |
| 3.20 | 90 | 4.20 | 400 | 5.10 | 1,005 | 6.00 | 1,840 |
| 3.30 | 110 | 4.30 | 450 | 5.20 | 1,090 | 6.10 | 1,940 |
| 3.40 | 132 | 4.40 | 505 | 5.30 | 1,180 | 6.20 | 2,040 |
| 3.50 | 156 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on 16 discharge measurements made during 1904–5. It is well defined.

*Estimated monthly discharge of Umatilla River at Yoakum, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 770 | 156 | 320 | 19,680 |
| February | 505 | 156 | 273 | 15,160 |
| March | 2,040 | 505 | 826 | 50,790 |
| April | 1,940 | 505 | 1,153 | 68,610 |
| May | 1,180 | 355 | 683 | 42,000 |
| June | 355 | 90 | 212 | 12,620 |
| July | 110 | 20 | 51.1 | 3,142 |
| August | 28 | 20 | 23.9 | 1,470 |
| September | 156 | 28 | 48.2 | 2,868 |
| October | 110 | 59 | 78.7 | 4,839 |
| November | 132 | 90 | 105 | 6,248 |
| December | 565 | 132 | 368 | 22,630 |
| The year | 2,040 | 20 | 345. | 250,100 |

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## UMATILLA RIVER NEAR UMATILLA, OREG.

This station was established October 21, 1903, by John H. Lewis. It is located about 2½ miles above Umatilla, Oreg., and about one-fourth mile below the diversion dam of the Oregon Land and Water Company. This dam diverts water into an irrigation ditch on the left bank. To obtain the total discharge of the river, the discharge of the irrigation ditch must be added to that of the river at the cable. For estimate of flow in the ditch see page 201.

The channel is straight for 500 feet above and 1,000 feet below the cable. The current is swift. Both banks are high and rocky and will not overflow. The bed of the stream is composed of solid rock and is free from vegetation and permanent. Owing to the rapids just above Umatilla backwater from Columbia River does not affect the gage heights at the station.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is the zero mark on the tagged wire, directly over the vertical portion of the left bank.

An inclined gage is placed on the left bank 45 feet below the cable, and is in two sections. The lower section reads from 1.2 to 3.5 feet. The upper section reads from 3.5 to 10.8 feet. During 1905 the gage was read every other day during ordinary stages and once each day during floods by B. V. Pompella. The bench mark is the head of a bolt cemented in the solid rock 1½ feet upstream from the gage rod; elevation, 10.30 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 100, p 359; 135, pp 263-264.
Discharge: 100, p 360; 135, p 264.
Discharge, monthly: 135, p 266.
Gage heights: 100, p 360; 135, pp 264-265.
Rating table: 135, p 265.

*Discharge measurements of Umatilla River near Umatilla, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| February 28 | J. H. Lewis | 170 | 218 | 2.78 | 3.37 | 606 |
| March 27 | do | 177 | 379 | 4.54 | 4.22 | 1,722 |
| April 10 | do | 186 | 330 | 4.17 | 3.95 | 1,377 |
| May 12 | W. C. Sawyer | 175 | 280 | 3.94 | 3.70 | 1,103 |
| July 19 | do | | | | 1.60 | a0.1 |
| September 26 | do | 7.3 | 4.7 | .85 | 1.82 | 4.0 |
| October 25 | Sawyer and Hall | 31 | 38 | 1.63 | 2.41 | 62 |
| December 6 | R. S. Hall | 167 | 148 | 2.06 | 3.00 | 304 |

a Estimated.

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*Daily gage height, in feet, of Umatilla River near Umatilla, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.8 | | | 3.85 | | 3.05 | 2.3 | | 1.6 | 1.9 | | |
| 2 | | 3.15 | 3.35 | | 3.15 | | | 1.6 | | | 2.43 | 2.68 |
| 3 | 2.85 | | | 4.2 | | 2.95 | 2.1 | | 1.6 | 2.2 | | |
| 4 | | 3.05 | 3.4 | | 3.25 | | | 1.61 | | | 2.43 | 2.7 |
| 5 | 2.85 | | | 4.1 | | 2.9 | 1.8 | | 1.6 | 2.18 | | |
| 6 | | 3.0 | 3.4 | 4.2 | 3.6 | | | 1.61 | | | 2.43 | 3.0 |
| 7 | 2.8 | | | | | 2.9 | 1.7 | | 1.6 | 2.21 | | |
| 8 | | 2.9 | 3.3 | 4.15 | 3.6 | | | 1.61 | | | 2.41 | 3.0 |
| 9 | 2.8 | | | | | 2.8 | 1.65 | | 1.6 | 2.25 | | |
| 0 | | 2.9 | 3.2 | 3.95 | 3.7 | | | 1.6 | | | 2.4 | 3.0 |
| 1 | 2.8 | | | | | 2.7 | 1.6 | | 1.62 | 2.3 | | |
| 2 | | 2.9 | 3.2 | 3.7 | 3.8 | | | 1.6 | | | 2.4 | 2.95 |
| 3 | 2.95 | | | | | 2.6 | 1.55 | | 2.27 | 2.3 | | |
| 4 | | 2.75 | 3.2 | 3.65 | 3.7 | | | 1.7 | | | 2.4 | 2.9 |
| 5 | 2.95 | | | | | 2.45 | 1.5 | | 2.35 | 2.36 | | |
| 6 | | 2.8 | 3.15 | 3.5 | 3.45 | | | 1.6 | | | 2.45 | 2.85 |
| 7 | 2.9 | | | | | 2.3 | 1.5 | | 2.1 | 2.4 | | |
| 8 | | 2.8 | 3.2 | 3.45 | 3.4 | | | 1.6 | | | 2.42 | 2.9 |
| 9 | 2.7 | | | | | 2.2 | 1.6 | | 2.0 | 2.41 | | |
| 0 | | 2.8 | 3.15 | 3.4 | 3.2 | | | 1.6 | | | 2.45 | 3.1 |
| 1 | 2.7 | | | | | 2.2 | 1.6 | | 1.89 | 2.43 | | |
| 2 | | 2.8 | 3.25 | 3.55 | 3.1 | | | 1.6 | | | 2.5 | 3.0 |
| 3 | 2.75 | | | | | 1.9 | 1.6 | | 1.89 | 2.42 | | |
| 4 | | 2.85 | 3.5 | 3.6 | 3.1 | | | 1.6 | | | 2.5 | 2.95 |
| 5 | 3.15 | | | | | 2.2 | 1.59 | | 1.89 | 2.45 | | |
| 6 | | 3.15 | 3.8 | 3.5 | 3.2 | 2.4 | | 1.6 | | | 2.5 | 2.95 |
| 7 | 3.45 | | 4.22 | | | 2.35 | 1.6 | | 1.8 | 2.5 | | |
| 8 | | 3.37 | 4.3 | 3.4 | 3.15 | | | 1.6 | | | 2.55 | 2.9 |
| 9 | 3.4 | | 4.3 | | | 2.3 | 1.65 | | 1.89 | 2.5 | | |
| 0 | | | 4.0 | 3.2 | 3.1 | | | 1.6 | | | 2.65 | 2.9 |
| 1 | 3.3 | | | | | | 1.6 | | | 2.43 | | |

*Station rating table for Umatilla River near Umatilla, Oreg., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.00 | 13 | 2.60 | 110 | 3.20 | 480 | 3.80 | 1,170 |
| 2.10 | 21 | 2.70 | 145 | 3.30 | 580 | 3.90 | 1,310 |
| 2.20 | 32 | 2.80 | 190 | 3.40 | 690 | 4.00 | 1,450 |
| 2.30 | 45 | 2.90 | 245 | 3.50 | 800 | 4.10 | 1,590 |
| 2.40 | 62 | 3.00 | 310 | 3.60 | 920 | 4.20 | 1,740 |
| 2.50 | 83 | 3.10 | 390 | 3.70 | 1,040 | 4.30 | 1,890 |

The above table is applicable only for open-channel conditions. It is based on 16 discharge measurements made during 1903–1905. It is well defined.

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*Estimated monthly discharge of Umatilla River near Umatilla, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 745 | 145 | 307 | 18,880 |
| February | 557 | 168 | 283 | 15,730 |
| March | 1,890 | 435 | 764 | 46,990 |
| April | 1,740 | 480 | 1,085 | 64,560 |
| May | 1,170 | 390 | 670 | 41,200 |
| June | 350 | 8 | 122 | 7,260 |
| July | 45 | .0 | 4.62 | 284 |
| August | 1.5 | .1 | .21 | 13 |
| September | 54 | .1 | 11 | 654 |
| October | 83 | 8 | 53.2 | 3,271 |
| November | 128 | 62 | 75.8 | 4,510 |
| December | 390 | 138 | 263 | 16,170 |
| The year | 1,890 | .0 | 303 | 219,500 |

NOTE.—Mean for actual number of days recorded taken as the mean for the entire month.

## DITCHES IN UMATILLA RIVER VALLEY, OREGON.

### FARMERS' MILL DITCH AT PENDLETON, OREG.

Water is taken from Umatilla River just above the Main Street Bridge (upon a pier of which the river gage is located), is used to furnish power for the Farmers' flour mill, and then returned to the river above the railroad bridge at which river measurements were made.

The flow is not uniform during the low-water season because of storage in Byer's mill ditch above, and consequently measurements were discontinued.

*Discharge measurements of Farmers' mill ditch at Pendleton, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet* | *Second-feet.* |
| February 24 | Lewis and Yates | 24 | 28.3 | 2.13 | 0.82 | 60 |
| February 27 | Sawyer and Yates | 28 | 43.3 | 2.80 | 1.35 | 121 |
| April 6 | do | 23 | 41.8 | 4.98 | 1.66 | 208 |

*Daily gage height, in feet, of Farmers' mill ditch at Pendleton, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | Day. | Jan. | Feb. | Mar. | Apr. | May. | June. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.1 | 0.93 | 1.29 | 1.31 | 0.7 | 0.5 | 17 | 1.02 | 0.52 | 1.08 | 0.9 | ..... | ..... |
| 2 | 1.09 | .92 | 1.28 | 1.55 | .6 | .45 | 18 | 1.03 | .46 | 1.08 | .85 | 0.7 | ..... |
| 3 | 1.09 | .85 | 1.29 | 1.58 | .7 | .51 | 19 | 1.03 | .45 | 1.08 | .82 | .65 | ..... |
| 4 | 1.08 | .81 | 1.29 | 1.5 | .8 | .5 | 20 | 1.03 | .45 | 1.09 | 1.05 | .6 | ..... |
| 5 | 1.08 | .76 | 1.29 | 1.55 | .97 | .48 | 21 | 1.09 | .5 | 1.23 | 1.12 | .57 | ..... |
| 6 | 1.07 | .71 | 1.28 | 1.65 | 1.0 | .45 | 22 | ..... | .57 | 1.33 | 1.1 | .55 | ..... |
| 7 | 1.06 | .68 | 1.22 | 1.61 | 1.0 | .4 | 23 | 1.28 | .67 | 1.48 | 1.12 | .55 | ..... |
| 8 | 1.06 | .65 | 1.18 | 1.48 | .95 | .38 | 24 | 1.33 | .78 | 1.76 | 1.12 | .55 | ..... |
| 9 | 1.05 | .6 | 1.08 | 1.35 | 1.1 | .34 | 25 | 1.6 | 1.18 | 1.7 | 1.08 | .75 | ..... |
| 10 | 1.05 | .6 | 1.05 | 1.28 | 1.06 | .3 | 26 | 1.51 | 1.34 | 1.86 | 1.02 | .78 | ..... |
| 11 | 1.05 | .7 | 1.05 | 1.15 | 1.12 | .28 | 27 | 1.38 | 1.34 | 1.88 | .92 | .78 | ..... |
| 12 | 1.05 | .55 | 1.03 | 1.12 | 1.18 | .28 | 28 | 1.39 | 1.3 | 1.7 | .83 | .7 | ..... |
| 13 | 1.05 | 1.01 | .98 | 1.08 | 1.12 | ..... | 29 | 1.35 | ..... | 1.49 | .73 | .69 | ..... |
| 14 | 1.05 | 1.0 | 1.11 | 1.02 | 1.05 | ..... | 30 | 1.27 | ..... | 1.38 | .7 | .6 | ..... |
| 15 | 1.02 | .98 | 1.11 | .92 | .95 | ..... | 31 | 1.13 | ..... | ..... | ..... | .55 | ..... |
| 16 | 1.02 | .6 | 1.08 | .9 | .85 | ..... | | | | | | | |

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### HORSESHOE IRRIGATION COMPANY'S DITCH AT YOAKUM, OREG.

This ditch was dug during the latter part of 1904, and plans are being considered to enlarge and extend it. It diverts water from the left bank of Umatilla River, 1 mile above Yoakum, at Dehaven's ranch. No measurements were made during 1905. No water was used after the last of July.

### SLUSHER & GOULD DITCH NEAR NOLIN, OREG.

This ditch diverts water from the left bank of Umatilla River, 1¼ miles above Nolin, Oreg., and 8 miles above Echo.

Measurements were made in a flume near the head of the ditch.

*Discharge measurements of Slusher & Gould ditch near Nolin, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 18 | W. C. Sawyer | 2.29 | 0.76 | 0.71 | 1.74 |
| September 9 | F. C. Dillard | 1.23 | .46 | .44 | .56 |
| September 19 | do | .58 | .53 | .30 | .31 |
| September 25 | do | 1.14 | .57 | .44 | .65 |
| September 29 | do | 1.51 | .64 | .55 | .96 |
| October 4 | do | 1.32 | .59 | .50 | .78 |
| October 10 | do | 1.55 | .44 | .48 | .68 |
| October 17 | do | 1.13 | .48 | .46 | .54 |
| October 23 | do | 1.21 | .45 | .49 | .55 |
| October 30 | do | 1.18 | .47 | .48 | .56 |
| November 7 | do | 1.04 | .46 | .44 | .48 |
| November 13 | do | .59 | .36 | .30 | .21 |
| November 20 | do | 1.03 | 38 | .40 | .39 |
| December 21 | do | 3.16 | .75 | .80 | 2.38 |

### LISLE & CRANE DITCH NEAR ECHO, OREG.

This ditch diverts water from the right bank of Umatilla River, 2 miles below Nolin.

Measurements were made in a flume just below where the ditch is crossed by the Oregon Railroad and Navigation Company's track.

*Discharge measurements of Lisle & Crane ditch near Echo, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 18 | W. C. Sawyer | 8.62 | 0.52 | ..... | 4.50 |
| August 30 | Sawyer and Dillard | 4.29 | .65 | 1.26 | 2.79 |
| September 9 | F. C. Dillard | 5.72 | 1.20 | 1.61 | 6.86 |
| September 14 | do | 5.06 | .97 | 1.43 | 4.92 |
| September 19 | do | 5.64 | 1.16 | 1.55 | 6.54 |
| September 25 | do | 5.27 | 1.02 | 1.48 | 5.40 |
| September 29 | do | 6.27 | 1.27 | 1.68 | 7.99 |
| October 9 | do | 5.86 | 1.17 | 1.61 | 6.84 |
| October 12 | do | 4.37 | .59 | 1.27 | 2.58 |

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### CHARLES LISLE DITCH AT ECHO, OREG.

This ditch diverts water from the left bank of Umatilla River, 2½ miles above Echo.

*Discharge measurements of Charles Lisle ditch at Echo, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 18 | W. C. Sawyer | 4.78 | 2.98 | 0.62 | 1.42 |
| August 30 | F. C. Dillard | 4.86 | .18 | .64 | .88 |
| September 8 | do | 11.37 | .42 | 1.31 | 4.74 |
| September 19 | do | 9.70 | .51 | 1.16 | 4.97 |
| September 25 | do | 6.24 | .49 | .81 | 3.04 |
| October 4 | do | 5.17 | .47 | .71 | 2.44 |
| October 7 | do | 5.65 | .43 | .76 | 2.41 |
| October 9 | do | 5.58 | .44 | .77 | 2.44 |
| October 12 | do | 5.64 | .4 | .78 | 2.28 |
| October 17 | do | 5.70 | .45 | .79 | 2.53 |
| October 21 | do | 5.93 | .32 | .80 | 1.90 |
| October 23 | do | 5.69 | .38 | .80 | 2.15 |
| October 26 | do | 5.91 | .32 | .82 | 1.92 |
| October 30 | do | 6.25 | .32 | .87 | 1.98 |
| November 2 | do | 6.24 | .29 | .88 | 1.82 |
| November 7 | do | 6.40 | .25 | .87 | 1.59 |
| November 10 | do | 6.51 | .24 | .90 | 1.56 |
| November 13 | do | 6.84 | .24 | .91 | 1.64 |
| November 16 | do | 7.01 | .24 | .96 | 1.68 |
| November 21 | do | 7.66 | .20 | 1.01 | 1.5 |
| November 23 | do | 7.48 | .21 | 1.00 | 1.55 |
| December 5 | do | 7.57 | .24 | 1.00 | 1.82 |
| December 12 | do | 7.14 | .24 | .96 | 1.73 |

### HENRIETTA MILL DITCH AT ECHO, OREG.

This ditch diverts water from the right bank of Umatilla River, 2 miles above Echo.

The water was formerly used to furnish power for the Henrietta flour mill in Echo. At present a portion of the water is used for irrigation and the remainder wasted into the river below the mill.

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*Discharge measurements of Henrietta mill ditch at Echo, Oreg., in 1905.*

| Date | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 18 | W. C. Sawyer | 6.47 | 0.80 | 1.19 | 5.20 |
| August 19 | do | 5.56 | .92 | 1.14 | 5.10 |
| August 30 | Sawyer and Dillard | 3.55 | .40 | .69 | 1.42 |
| September 8 | F. C. Dillard | 2.99 | .42 | ..... | 1.26 |
| September 23 | do | 2.95 | .60 | .79 | 1.76 |
| September 25 | do | 2.16 | .51 | .67 | 1.11 |
| October 4 | do | 1.45 | .4 | .57 | .58 |
| October 7 | do | 1.30 | .38 | .55 | .49 |
| October 9 | do | 1.09 | .38 | .52 | .41 |
| October 12 | do | 1.04 | .36 | .50 | .37 |
| October 17 | do | .79 | .33 | .43 | .26 |
| October 21 | do | .70 | .21 | .40 | .15 |
| October 23 | do | .66 | .23 | .40 | .15 |
| October 26 | do | .55 | .40 | .40 | .22 |
| October 30 | do | 3.00 | .42 | .80 | 1.27 |
| November 2 | do | 2.87 | .35 | .80 | 1.01 |
| November 7 | do | 2.75 | .30 | .77 | .83 |
| November 10 | do | 2.55 | .31 | .73 | .78 |
| November 13 | do | 2.43 | .3 | .70 | .73 |
| November 16 | do | 2.51 | .27 | .74 | .69 |
| November 21 | do | 2.5 | .26 | .70 | .64 |
| November 24 | do | 1.85 | .21 | .63 | .38 |
| December 5 | do | 1.19 | .23 | .48 | .27 |
| December 12 | do | 1.17 | .21 | .50 | .25 |
| December 21 | do | 7.38 | .77 | 1.61 | 5.66 |
| December 27 | do | 7.2 | .78 | 1.57 | 5.58 |

*Discharge measurements of Henrietta mill ditch wasteway at Echo, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 19 | W. C. Sawyer | 2.35 | 0.45 | ..... | 1.05 |
| August 30 | Sawyer and Dillard | 2.52 | .47 | 0.53 | 1.19 |
| September 8 | ..... | 2.06 | .39 | .44 | .8 |
| September 23 | F. C. Dillard | .49 | .37 | ..... | .18 |
| September 23 | do | 2.19 | .44 | .50 | .96 |
| September 26 | do | 1.84 | .35 | .44 | .65 |
| October 5 | do | 1.49 | .27 | .34 | .46 |
| October 10 | do | 1.11 | .23 | .28 | .26 |
| October 13 | do | .89 | .19 | .19 | .17 |
| October 17 | do | .65 | .20 | .19 | .13 |
| October 21 | do | .55 | .18 | .12 | .10 |
| October 24 | do | .46 | .13 | .13 | .06 |
| October 30 | do | 1.98 | .38 | .45 | .75 |
| November 3 | do | 2.14 | .30 | .44 | .64 |
| November 8 | do | 1.78 | .28 | .39 | .49 |
| November 13 | do | 1.34 | .25 | .33 | .33 |
| November 16 | do | 1.56 | .19 | .38 | .30 |
| November 24 | do | 1.81 | .11 | .42 | .19 |

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### WILSON & CO.'S DITCH AT ECHO, OREG.

This ditch diverts water from the right bank of Umatilla River 2 miles above Echo, just below the Henrietta mill diversion.

Measurements were made about 500 feet below the waste gate.

The ditch was dug during 1904.

*Discharge measurements of Wilson & Co.'s ditch at Echo, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 18 | W. C. Sawyer | 7.4 | 0.73 | 2.07 | 5.41 |
| August 19 | do | 6.58 | .76 | 1.84 | 4.99 |
| August 30 | Sawyer and Dillard | 2.43 | .20 | 1.22 | .48 |
| September 8 | F. C. Dillard | 3.25 | .39 | 1.50 | 1.26 |
| September 23 | do | 8.98 | .38 | 2.20 | 3.41 |
| September 25 | do | 8.64 | .37 | 2.19 | 3.18 |
| October 4 | do | 4.13 | .32 | 1.64 | 1.32 |
| October 7 | do | 5.00 | .33 | 1.75 | 1.66 |
| October 9 | do | 5.45 | .35 | 1.82 | 1.93 |
| October 12 | do | 5.33 | .86 | 2.80 | 4.56 |
| October 17 | do | 5.72 | .37 | 1.91 | 2.11 |
| October 21 | do | 4.73 | .32 | 1.72 | 1.52 |
| October 23 | do | 4.28 | .31 | 1.65 | 1.34 |
| October 26 | do | 4.94 | .34 | 1.77 | 1.69 |
| October 30 | do | 5.40 | .34 | 1.81 | 1.86 |
| November 2 | do | 4.57 | .32 | 1.72 | 1.47 |
| November 7 | do | 4.60 | .31 | 1.70 | 1.42 |

### ALLEN DITCH AT ECHO, OREG.

This ditch diverts water from the left bank of Umatilla River 1 mile above Echo.

During the latter portion of 1905 a portion of the water was wasted into the Pioneer ditch and some into the river.

Measurements were made one-eighth mile below the head gate.

*Discharge measurements of Allen ditch at Echo, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 19 | W. C. Sawyer | 10.73 | 0.65 | ..... | 6.97 |
| August 29 | Sawyer and Dillard | 14.80 | .58 | ..... | 8.57 |
| September 8 | F. C. Dillard | 14.84 | .76 | ..... | 11.21 |
| September 16 | do | 5.52 | .57 | 0.42 | 3.14 |
| September 19 | do | 4.97 | .62 | .41 | 3.07 |
| September 23 | do | 12.66 | 1.34 | .99 | 16.58 |
| September 25 | do | 13.30 | 1.29 | 1.0 | 17.30 |
| September 30 | Sawyer and Dillard | 15.71 | 1.47 | 1.07 | 23.13 |
| October 4 | F. C. Dillard | 15.30 | 1.42 | 1.01 | 21.64 |
| October 7 | do | 11.96 | 1.05 | .69 | 12.52 |
| October 9 | do | 11.81 | 1.0 | .68 | 11.85 |
| October 12 | do | 11.76 | 1.02 | .67 | 11.97 |
| October 17 | do | 11.05 | 1.04 | .65 | 11.51 |
| October 21 | do | 11.65 | 1.04 | .65 | 12.11 |

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*Discharge measurements of Allen ditch at Echo, Oreg., in 1905*—Continued.

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| October 24 | F. C. Dillard | 11.57 | 1.05 | 0.63 | 12.17 |
| October 27 | do | 16.21 | .74 | 1.17 | 12.08 |
| October 31 | do | 15.88 | .75 | 1.15 | 11.94 |
| November 3 | do | 16.04 | .76 | 1.14 | 12.14 |
| November 8 | do | 15.88 | .74 | 1.16 | 11.70 |
| November 11 | do | 15.54 | .73 | 1.15 | 11.52 |
| November 14 | do | 15.92 | .75 | 1.17 | 11.97 |
| November 17 | do | 15.93 | .75 | 1.16 | 11.89 |
| November 21 | do | 17.06 | .68 | 1.29 | 11.55 |
| November 24 | do | 15.44 | .79 | 1.12 | 12.17 |
| December 5 | do | 25.90 | .30 | .92 | 7.76 |
| December 13 | do | 13.12 | .26 | .92 | 3.44 |
| December 21 | do | 15.89 | .97 | 1.21 | 15.40 |

*Discharge measurements of Allen ditch wasteway at Echo, Oreg., in 1905.*

| Date | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| September 23 | F. C. Dillard | 1.23 | 0.10 | ..... | 0.12 |
| September 30 | Sawyer and Dillard | 2.74 | 1.18 | ..... | 3.24 |
| October 5 | F. C. Dillard | 2.64 | 1.13 | ..... | 2.98 |
| October 7 | do | 2.54 | .94 | ..... | 2.40 |
| October 9 | do | 2.35 | .97 | ..... | 2.28 |
| October 12 | do | 2.86 | 1.03 | ..... | 2.94 |
| October 18 | do | 2.66 | .94 | 0.48 | 2.53 |
| October 21 | do | 2.58 | .90 | .48 | 2.31 |
| October 24 | do | 2.65 | .91 | .47 | 2.42 |
| October 26 | do | 1.80 | .18 | .25 | .32 |
| October 31 | do | 1.78 | .12 | .25 | .22 |
| November 2 | do | 1.79 | .21 | .36 | .37 |
| December 13 | do | 2.41 | .48 | ..... | 1.17 |
| December 21 | do | 4.86 | 2.23 | .81 | 10.08 |
| December 27 | do | 5.21 | 1.71 | .80 | 8.89 |

### HINKLE DITCH AT ECHO, OREG.

This ditch diverts water from the left bank of Umatilla River 1 mile above Echo. The ditch was dry during August, September, and most of October. Measurements were made at a wagon bridge just below the waste gate. The waste is so arranged that water may be turned into the Allen ditch or the Allen ditch wasteway.

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*Discharge measurements of Hinkle ditch at Echo, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| October 27 | F. C. Dillard | 7.27 | 0.81 | 1.36 | 5.86 |
| October 31 | do | 7.97 | .79 | 1.39 | 6.29 |
| November 2 | do | 9.37 | .71 | 1.39 | 6.60 |
| November 8 | do | 8.24 | .69 | 1.33 | 5.71 |
| November 10 | do | 10.13 | .76 | 1.50 | 7.70 |
| November 14 | do | 11.69 | .83 | 1.52 | 9.65 |
| November 16 | do | 10.83 | .74 | 1.52 | 8.00 |
| November 21 | do | 13.69 | 1.00 | 1.74 | 13.78 |
| November 23 | do | 13.91 | .95 | 1.74 | 13.24 |
| November 30 | do | 13.57 | .93 | 1.76 | 12.69 |
| December 5 | do | 11.73 | .97 | 1.60 | 11.40 |
| December 27 | do | 13.28 | .97 | 1.71 | 12.87 |

### PIONEER DITCH AT ECHO, OREG.

This ditch diverts water from the left bank of Umatilla River west of the city of Echo. All of the water during the latter part of September, October, and November was waste from the Allen ditch. During December a small portion of the water came directly from the river. Measurements were made from the wagon bridge just below the Allen ditch wasteway.

*Discharge measurements of Pioneer ditch at Echo, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| September 23 | F. C. Dillard | 6 30 | 0.66 | 0.94 | 4.14 |
| September 25 | do | 2.52 | .52 | .51 | 1.31 |
| September 30 | Sawyer and Dillard | 6.62 | .94 | 1.09 | 6.22 |
| October 5 | F. C. Dillard | 6.16 | .84 | .95 | 5.20 |
| October 7 | do | 5.05 | .69 | .84 | 3.50 |
| October 9 | do | 5.78 | .74 | .91 | 4.25 |
| October 12 | do | 7.85 | .84 | 1.09 | 6.63 |
| October 18 | do | 8.73 | .89 | 1.18 | 7.72 |
| October 21 | do | 9.26 | .84 | 1.23 | 7.74 |
| October 24 | do | 9.47 | .81 | 1.26 | 7.64 |
| October 26 | do | 3.92 | .67 | .70 | 2.62 |
| October 31 | do | 4.32 | .61 | .76 | 2.62 |
| November 2 | do | 3.10 | .52 | .60 | 1.61 |
| November 8 | do | 10.31 | .81 | 1.32 | 8.34 |
| November 10 | do | 10.28 | .83 | 1.36 | 8.52 |
| November 14 | do | 11.40 | .85 | 1.48 | 9.65 |
| November 16 | do | 9.71 | .80 | 1.34 | 7.78 |
| November 21 | do | 10.80 | .85 | 1.43 | 8.63 |
| November 23 | do | 10.66 | .86 | 1.43 | 9.13 |
| December 13 | do | 12.55 | 1.03 | 1.58 | 12.98 |
| December 21 | do | 4.42 | .58 | .74 | 2.54 |
| December 27 | do | 3.39 | .50 | .73 | 1.71 |

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### MAXWELL DITCH AT ECHO, OREG.

This ditch diverts water from the left bank of Umatilla River 2 miles below Echo. Measurements were made 1,000 feet below the head gate. At a point 1 mile below the head the water is carried under the river in a siphon and the surplus wasted into the river.

*Discharge measurements of Maxwell ditch at Echo, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 8 | Sawyer and Dillard | 2.36 | 0.68 | ..... | 1.61 |
| August 30 | F. C. Dillard | 1.68 | .39 | ..... | .49 |
| September 8 | do | 1.09 | .91 | ..... | .99 |
| September 16 | do | 3.02 | .96 | 0.52 | 2.89 |
| September 19 | do | 2.81 | .80 | .47 | 2.25 |
| September 25 | do | 3.22 | .92 | .52 | 2.96 |
| September 30 | Sawyer and Dillard | 6.70 | 1.48 | 1.02 | 9.90 |
| October 5 | F. C. Dillard | 8.02 | 1.70 | 1.24 | 13.65 |
| October 7 | do | 6.72 | 1.48 | 1.00 | 9.92 |
| October 9 | do | 6.34 | 1.51 | .98 | 9.61 |
| October 12 | do | 6.32 | 1.5 | .95 | 9.46 |
| October 18 | do | 5.78 | 1.43 | .89 | 8.25 |
| October 21 | do | 5.92 | 1.45 | .88 | 8.62 |
| October 24 | do | 5.73 | 1.44 | .88 | 8.25 |
| October 26 | do | 5.16 | 1.45 | .85 | 7.48 |
| October 31 | do | 4.92 | 1.28 | .75 | 6.28 |
| November 2 | do | 4.93 | 1.25 | .75 | 6.19 |
| November 8 | do | 5.00 | 1.18 | .69 | 5.92 |
| November 10 | do | 4.40 | 1.20 | .69 | 5.30 |
| November 14 | do | 4.33 | 1.21 | .69 | 5.23 |
| November 16 | do | 4.34 | 1.24 | .68 | 5.38 |
| November 21 | do | 4.07 | 1.16 | .66 | 4.72 |
| November 23 | do | 4.13 | 1.12 | .64 | 4.64 |
| December 13 | do | 2.72 | .83 | .44 | 2.26 |
| December 21 | do | 2.09 | .67 | .45 | 1.39 |
| December 27 | do | 1.97 | .57 | .33 | 1.13 |

*Discharge measurements of Maxwell ditch wasteway at Echo, Oreg., in 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| | | *Second-feet.* |
| October 5 | F. C. Dillard | 1.02 |
| October 10 | do | 1.11 |
| October 13 | do | 1.21 |
| October 18 | do | 1.14 |
| October 21 | do | 1.28 |
| October 24 | do | 1.30 |
| October 26 | do | 1.40 |
| October 31 | do | 2.29 |
| November 2 | do | 2.07 |

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### HERMISTON DITCH NEAR HERMISTON, OREG.

This ditch diverts water from the right bank of Umatilla River, 5 miles below Fosters, Oreg. Measurements were made just below the head-gate and below the second waste gate.

*Discharge measurements of Hermiston ditch below head-gate near Hermiston, Oreg., in 1905.*

| Date | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 9 | W. C. Sawyer | 6.53 | 0.6 | ..... | 3.92 |
| September 15 | F. C. Dillard | 19.15 | 1.24 | ..... | 23.83 |
| September 22 | do | 8.89 | .81 | 0.21 | 7.20 |
| September 27 | do | 11.31 | .79 | .39 | 8.99 |
| September 30 | Sawyer and Dillard | 13.02 | .86 | .48 | 11.14 |
| October 3 | F. C. Dillard | 13.35 | .88 | .49 | 11.77 |
| October 6 | do | 13.1 | .85 | .49 | 11.18 |
| October 11 | do | 13.99 | .84 | .50 | 11.80 |
| October 14 | do | 13.28 | .82 | .54 | 10.90 |
| October 20 | do | 13.86 | .89 | .50 | 12.28 |
| October 25 | do | 13.22 | .93 | .48 | 12.18 |
| October 28 | do | 12.65 | .9 | .47 | 11.38 |
| November 1 | do | 13.09 | .8 | .47 | 11.16 |
| November 3 | do | 14.31 | .78 | .53 | 11.10 |
| November 9 | do | 13.95 | .79 | .52 | 10.93 |
| November 15 | do | 14.00 | .81 | .55 | 11.30 |
| November 18 | do | 13.94 | .8 | .54 | 11.16 |
| November 22 | do | 13.83 | .77 | .54 | 10.63 |
| November 25 | do | 14.33 | .77 | .56 | 10.99 |
| December 6 | do | 14.02 | .81 | ..... | 11.31 |
| December 14 | do | 13.82 | .77 | ..... | 10.60 |

*Discharge measurements of Hermiston ditch below second wasteway near Hermiston, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 9 | W. C. Sawyer | 4.25 | 0.62 | ..... | 2.73 |
| September 22 | F. C. Dillard | 4.74 | 1.30 | 0.45 | 6.17 |
| September 27 | do | 3.15 | 1.12 | .30 | 3.54 |
| September 30 | Sawyer and Dillard | 4.22 | 1.31 | .45 | 5.55 |
| October 3 | F. C. Dillard | 4.75 | 1.34 | .50 | 6.38 |
| October 6 | do | 5.50 | 1.48 | .65 | 8.17 |
| October 11 | do | 3.76 | 1.09 | .35 | 4.10 |
| October 14 | do | 2.93 | 1.01 | .28 | 2.96 |
| October 20 | do | 5.78 | 1.50 | .70 | 8.69 |
| October 25 | do | 5.69 | 1.48 | .70 | 8.42 |
| October 28 | do | 5.31 | 1.44 | .62 | 7.66 |
| November 1 | do | 4.73 | 1.21 | .50 | 5.73 |
| November 3 | do | 2.60 | .99 | .20 | 2.56 |

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### BEITLE DITCH NEAR HERMISTON, OREG.

This ditch is now owned by D. C. Brownell, and diverts water from the right bank of Umatilla River west of Hermiston. Measurements were made just below the waste gate.

*Discharge measurements of Beitle ditch near Hermiston, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 9 | | 1.87 | 0.52 | ..... | 0.96 |
| September 15 | F. C. Dillard | 1.76 | .61 | 0.71 | 1.08 |
| October 3 | do | 1.04 | .163 | .50 | .17 |
| October 11 | do | 1.35 | .40 | .63 | .54 |
| October 14 | do | 1.39 | .45 | .64 | .62 |
| October 20 | do | 2.03 | .69 | .81 | 1.40 |
| October 25 | do | .74 | .95 | .46 | .07 |

### OREGON LAND AND WATER COMPANY'S DITCH AT UMATILLA, OREG.

This ditch diverts water from the left bank of Umatilla River 2 miles above Umatilla. Measurements were made opposite the river gaging station below the upper flume and waste gate, one-fourth mile below the diversion point. The gage was read every other day by B. V. Pompella and Clyde E. Niles.

*Discharge measurements of Oregon Land and Water Company's ditch at Umatilla, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| February 28 | J. H. Lewis | 15.8 | 1.74 | 2.00 | 27.5 |
| March 27 | do | 14.6 | 1.56 | 1.87 | 22.9 |
| April 10 | do | 16.1 | 1.84 | 2.00 | 29.6 |
| May 12 | W. C. Sawyer | 17.6 | 2.05 | 2.13 | 36.1 |
| July 19 | do | 12.4 | 1.47 | 1.83 | 18.2 |
| September 15 | F. C. Dillard | 12.5 | 1.28 | 1.83 | 16.0 |
| September 26 | W. C. Sawyer | 10.6 | 1.19 | 1.65 | 12.7 |
| October 25 | R. S. Hall | ..... | ..... | .75 | 0.0 |
| November 4 | F. C. Dillard | 10.3 | .96 | 1.53 | 9.8 |
| November 9 | do | 9.2 | 1.09 | 1.54 | 9.4 |

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*Daily gage height, in feet of Oregon Land and Water Company's ditch at Umatilla, Oreg., for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | 1.8 | | 2.35 | 2.4 | | 1.71 | 1.68 | |
| 2 | 1.95 | | 2.0 | | | 1.73 | | | 1.53 |
| 3 | | 1.8 | | 2.15 | 2.4 | | 1.73 | 1.71 | |
| 4 | 1.9 | | 2.0 | | | 1.7 | | | 1.53 |
| 5 | | 1.8 | | 2.15 | 2.2 | | 1.75 | 1.55 | |
| 6 | 1.95 | 1.8 | 2.0 | | | 1.7 | | | 1.53 |
| 7 | | | | 2.15 | 2.0 | | 1.75 | 1.57 | |
| 8 | 1.95 | 2.0 | 2.15 | | | 1.72 | | | 1.53 |
| 9 | | | | 2.4 | 1.95 | | 1.77 | 1.57 | |
| 10 | 2.0 | 2.0 | 2.15 | | | 1.72 | | | 1.67 |
| 11 | | | | 2.4 | 1.9 | | 1.77 | 1.58 | |
| 12 | 2.0 | 2.0 | 2.15 | | | 1.72 | | | 1.67 |
| 13 | | | | 2.25 | 1.9 | | 1.77 | 1.43 | |
| 14 | 2.0 | 2.0 | 1.9 | | | 1.67 | | (a) | 1.67 |
| 15 | | | | 2.1 | 1.85 | | 1.9 | | |
| 16 | 1.85 | 2.0 | 2.15 | | | 1.75 | | | |
| 17 | | | | 2.4 | 1.85 | | 1.88 | | |
| 18 | 1.85 | 2.0 | 1.8 | | | 1.73 | | | |
| 19 | | | | 2.4 | 1.83 | | 1.86 | | |
| 20 | 1.85 | 1.95 | 2.05 | | | 1.71 | | | |
| 21 | | | | 2.4 | 1.83 | | 1.68 | | |
| 22 | 1.85 | 2.1 | 2.05 | | | 1.7 | | | |
| 23 | | | | 2.4 | 1.82 | | 1.65 | | |
| 24 | 1.9 | 2.1 | 2.4 | | | 1.7 | | | |
| 25 | | | | 2.4 | 1.8 | | 1.67 | | |
| 26 | 1.9 | 2.1 | 2.2 | | | 1.7 | | | |
| 27 | 1.87 | | | 2.35 | 1.79 | | 1.68 | | |
| 28 | 1.9 | 2.1 | 2.3 | | | 1.7 | | | |
| 29 | 1.9 | | | 2.4 | 1.81 | | 1.68 | | |
| 30 | 1.85 | 2.1 | 2.4 | | | 1.7 | | | |
| 31 | | | | | 1.8 | | | 1.53 | |

a Dry October 14-30.

*Station rating table for Oregon Land and Water Company's ditch at Umatilla, Oreg., from January 1 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.75 | 0.0 | 1.20 | 3.2 | 1.70 | 14.5 | 2.20 | 41.0 |
| .80 | .1 | 1.30 | 4.5 | 1.80 | 18.5 | 2.30 | 50.0 |
| .90 | .5 | 1.40 | 6.3 | 1.90 | 23.1 | 2.40 | 60.0 |
| 1.00 | 1.2 | 1.50 | 8.5 | 2.00 | 28.2 | 2.50 | 73.0 |
| 1.10 | 2.1 | 1.60 | 11.1 | 2.10 | 34.0 | | |

The above table is applicable only for open-channel conditions. It is based on ten discharge measurements made during 1905. It is well defined between gage heights 1.65 feet and 2.1 feet.

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*Estimated monthly discharge of Oregon Land and Water Company's ditch at Umatilla, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| March | 28.2 | 19.6 | 23.8 | 1,463 |
| April | 34.0 | 18.5 | 27.5 | 1,636 |
| May | 60.0 | 18.5 | 36.9 | 2,269 |
| June | 60.0 | 34.0 | 52.2 | 3,106 |
| July | 60.0 | 18.1 | 26.8 | 1,648 |
| August | 17.1 | 13.4 | 15.0 | 922 |
| September | 23.1 | 12.7 | 16.6 | 988 |
| October | 14.9 | 0 | 4.89 | 301 |
| November | 13.4 | 9.2 | 10.8 | 300 |
| The period | | | | 12,630 |

NOTE.—Mean for actual number of days recorded taken as the mean for the entire month.

### BROWNELL DITCH AT UMATILLA, OREG.

This ditch diverts water from the right bank of Umatilla River 1½ miles above Umatilla, Oreg., and a few hundred feet below the river-gaging station. Measurements were made below the Oregon Railroad and Navigation Company's sidetrack.

*Discharge measurements of Brownell ditch at Umatilla, Oreg., in 1905.*

| Date. | Hydrographer. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|
| | | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| May 12 | W. C. Sawyer | 7.50 | 0.73 | | 5.50 |
| September 26 | do | 3.80 | 1.03 | 1.17 | 3.90 |
| October 25 | R. S. Hall | 3.28 | .65 | 1.05 | 2.13 |
| October 28 | F. C. Dillard | 2.95 | .58 | 1.05 | 1.72 |
| November 1 | do | 2.79 | .50 | 1.02 | 1.41 |
| November 3 | do | 2.77 | .51 | 1.00 | 1.41 |
| November 9 | do | 3.06 | .64 | 1.09 | 1.95 |
| November 15 | do | 3.06 | .65 | 1.09 | 1.98 |
| November 18 | do | 3.06 | .65 | 1.09 | 1.98 |
| November 22 | do | 3.09 | .63 | 1.09 | 1.96 |
| November 25 | do | 3.08 | .64 | 1.09 | 1.98 |
| December 6 | R. S. Hall | 3.28 | .82 | 1.11 | 2.70 |
| December 14 | F. C. Dillard | 3.28 | .68 | 1.12 | 2.23 |
| December 20 | Dillard and Hall | 3.47 | .74 | 1.14 | 2.58 |

### BOWMAN DITCH AT UMATILLA, OREG.

This ditch diverts water from the right bank of Umatilla River one-half mile above Umatilla. December 20, 1905, a discharge measurement made by Dillard and Hall gave a discharge of 0.33 second-foot.

### SPRINGS IN UMATILLA RIVER VALLEY.

The following discharge measurements were made in 1905, by F. C. Dillard, of springs in Umatilla River Valley:

Gillette Springs outlet, near Echo, Oreg., October 2, 1.95 second-feet.

Cold Springs, near Hermiston, Oreg., September 27, 1.65 second-feet; October 6, 1.50 second-feet.



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## WILLOW CREEK DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Willow Creek rises on the northern slopes of the western spur of the Blue Mountains and flows northwestward, entering Columbia River at Willows, Oreg.

### WILLOW CREEK NEAR ARLINGTON, OREG.

This station was established December 17, 1904. It is located at the wagon bridge at Rhea Siding, 9 miles from Arlington, Oreg. The station is maintained as a flood station and miscellaneous measurements only are made during the summer season.

The channel is curved, but in high water is fairly straight for 100 feet. Both banks are high and clean and overflow but rarely. The bed of the stream is composed of rocks and gravel and is free from vegetation and permanent. There is but one channel.

Discharge measurements are made from the bridge or by wading.

A vertical-staff gage is fastened to a bent of the bridge. During 1905 the gage was read once each day by C. H. Curtis.

*Discharge measurements of Willow Creek near Arlington, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| March 16 | W. C. Sawyer | 12 | 8 | 2.21 | 3.38 | 17.6 |
| March 26 | J. H. Lewis | 27 | 25 | 2.26 | 3.77 | 56 |
| April 9 | do | 24 | 28 | 2.46 | 3.85 | 69 |
| May 31 | W. C. Sawyer | 14 | 56 | 2.82 | 4.40 | 157 |
| May 31 | do | 18 | 63 | 2.98 | 4.50 | 187 |
| May 31 | do | 14 | 46 | 2.19 | 4.18 | 112 |
| August 17 | do | 5 | 1.5 | .85 | 3.00 | 1.3 |
| October 24 | Sawyer and Hall | 4 | 2.3 | 1.59 | 3.11 | 3.7 |
| December 19 | Hall and Dillard | 9 | 6.5 | 1.79 | 3.29 | 11.6 |

NOTE.—These measurements were made at different sections.

*Daily gage height, in feet, of Willow Creek near Arlington, Oreg., for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Day. | Mar. | Apr. | May. | June. | July. | Aug. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.7 | 3.8 | 2.9 | 3.75 | 3.0 | 3.0 | 17 | 3.7 | 3.4 | 3.25 | 3.0 | 2.9 | 3.0 |
| 2 | 3.7 | 4.0 | 2.8 | 3.75 | 3.0 | 3.0 | 18 | 3.7 | 3.5 | 3.25 | 3.0 | 2.9 | 3.0 |
| 3 | 3.7 | 4.1 | 2.8 | 3.7 | 3.0 | 2.8 | 19 | 3.7 | 3.4 | 3.3 | 3.0 | 2.8 | 3.1 |
| 4 | 3.6 | 4.1 | 2.9 | 3.7 | 3.0 | 2.8 | 20 | 3.8 | 3.35 | 3.3 | 3.0 | 2.8 | 3.1 |
| 5 | 3.6 | 4.0 | 2.8 | 3.7 | 3.0 | 2.8 | 21 | 3.8 | 3.35 | 3.3 | 3.0 | 2.8 | ..... |
| 6 | 3.6 | 3.95 | 2.8 | 3.7 | 3.0 | 2.9 | 22 | 3.8 | 3.3 | 3.3 | 2.95 | 2.8 | ..... |
| 7 | 3.6 | 3.9 | 2.8 | 3.55 | 2.8 | 3.0 | 23 | 3.8 | 3.1 | 3.2 | 2.9 | 2.8 | ..... |
| 8 | 3.5 | 3.9 | 2.8 | 3.45 | 2.8 | 3.0 | 24 | 3.9 | 3.0 | 3.2 | 2.8 | 2.8 | ..... |
| 9 | 3.5 | 3.85 | 2.8 | 3.45 | 2.8 | 3.0 | 25 | 4.0 | 3.0 | 3.3 | 5.4 | 2.8 | ..... |
| 10 | 3.5 | 3.85 | 2.8 | 3.45 | 3.0 | 3.0 | 26 | 3.9 | 3.0 | 3.3 | 4.9 | 2.8 | ..... |
| 11 | 3.5 | 3.85 | 2.8 | 3.4 | 2.95 | 2.9 | 27 | 3.9 | 2.9 | 3.3 | 3.6 | 2.8 | ..... |
| 12 | 3.5 | 3.8 | 2.8 | 3.4 | 2.9 | 2.9 | 28 | 3.9 | 2.9 | 3.3 | 3.45 | 2.8 | ..... |
| 13 | 3.5 | 3.5 | 2.8 | 3.4 | 2.9 | 2.8 | 29 | 3.9 | 2.9 | 3.3 | 3.3 | 2.9 | ..... |
| 14 | 3.5 | 3.45 | 3.5 | 3.3 | 2.9 | 3.0 | 30 | 3.9 | 2.9 | 3.3 | 3.0 | 2.9 | ..... |
| 15 | 3.6 | 3.45 | 3.5 | 3.2 | 2.9 | 3.0 | 31 | 3.9 | ..... | 4.33 | ..... | 3.0 | ..... |
| 16 | 3.6 | 3.4 | 3.3 | 3.2 | 2.9 | 3.0 | | | | | | | |

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*Station rating table for Willow Creek near Arlington, Oreg., from March 1 to August 20, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 2.80 | 0.3 | 3.50 | 28 | 4.20 | 120 | 4.90 | 299 |
| 2.90 | .6 | 3.60 | 38 | 4.30 | 139 | 5.00 | 333 |
| 3.00 | 1.3 | 3.70 | 48 | 4.40 | 160 | 5.10 | 369 |
| 3.10 | 3.8 | 3.80 | 60 | 4.50 | 183 | 5.20 | 406 |
| 3.20 | 7 | 3.90 | 73 | 4.60 | 209 | 5.30 | 445 |
| 3.30 | 13 | 4.00 | 87 | 4.70 | 237 | 5.40 | 488 |
| 3.40 | 20 | 4.10 | 103 | 4.80 | 267 | | |

The above table is applicable only for open-channel conditions. It is based on eight discharge measurements made during 1905. It is well defined between gage heights 3 feet and 4.5 feet. The table has been extended beyond these limits.

*Estimated monthly discharge of Willow Creek near Arlington, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| March | 87 | 28 | 50.0 | 3,074 |
| April | 103 | .6 | 38.1 | 2,267 |
| May | 145 | .3 | 12.3 | 756 |
| June | 488 | .3 | 45.5 | 2,707 |
| July | 1.3 | .3 | .67 | 41 |
| August 1-20 | 3.8 | .3 | 1.24 | 49 |
| The period | | | | 8,894 |

## JOHN DAY RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

John Day River enters Columbia River from the south. For about 90 miles above its mouth the river flows in a northerly direction through a rolling country partly desert and partly cultivated and comprising, approximately, 2,000 square miles. This portion of the river receives a number of small tributaries, but only one of importance—Rock Creek—which joins the river a mile above the gaging station at McDonald. The river channel is for the most part several hundred feet below the level of the surrounding country, and as the river bottom is narrow very little water is used for irrigation.

In the upper section the river flows in a westerly direction and is joined by three important tributaries—North, Middle, and South forks. The first two flow in a westerly direction also, but the latter comes from the south. This upper portion of the river drains a country much of which is from 4,000 to 10,000 feet in elevation and which includes the western slopes of the Blue Mountains. The higher portions are still well timbered.

### JOHN DAY RIVER AT M'DONALD, OREG.

This station was established November 14, 1904, by W. C. Sawyer. It is located at the ferry at McDonald, 16 miles above the mouth of the river and 18 miles southwest of Arlington, Oreg.

The channel is straight for one-half mile above and below the cable. The current is swift. Both banks are high, free from vegetation, and do not overflow. The bed of the stream is composed of clean sand and gravel and is slightly shifting. There is but one channel at all stages.

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Discharge measurements are made by means of a car suspended from the ferry cable. The car is provided with steel blocks and lever for passing the ferry traveler. The initial point for soundings is the face of the support on the right bank.

An inclined staff gage in two sections is fastened to old bridge timbers 183 feet upstream from the ferry cable. The lower section reads from 1 to 2 feet; the upper section reads from 2 to 11 feet. During 1905 the gage was read once each day by William Murray. The bench mark is the top of the corner stone under the southeast corner of a barn near the gage; elevation, 15.32 feet above the datum of the gage.

A description of this station, with gage heights and discharge data, is contained in Water-Supply Paper No. 135, United States Geological Survey, page 268.

*Discharge measurements of John Day River at McDonald, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| February 24 | W. C. Sawyer | 278 | 953 | 2.07 | 3.20 | 1,970 |
| March 17 | do | 285 | 1,067 | 2.48 | 3.66 | 2,650 |
| March 25 | J. H. Lewis | 300 | 1,214 | 2.89 | 4.10 | 3,500 |
| April 8 | do | 304 | 1,252 | 3.05 | 4.28 | 3,820 |
| May 10 | W. C. Sawyer | 308 | 1,393 | 3.59 | 4.70 | 5,000 |
| May 11 | do | 310 | 1,368 | 3.54 | 4.68 | 4,850 |
| June 1 | do | 277 | 1,047 | 2.27 | 3.58 | 2,380 |
| August 16 [a] | do | 50 | 50 | 2.14 | 1.25 | 107 |
| August 17 [a] | do | 58 | 48 | 2.29 | 1.25 | 110 |
| October 23 | Sawyer and Hall | 258 | 578 | .60 | 1.75 | 350 |
| October 24 | W. C. Sawyer | 258 | 556 | .60 | 1.73 | 330 |

[a] Made at different section.

*Daily gage height, in feet, of John Day River at McDonald, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.5 | 2.8 | 3.45 | 3.8 | 3.9 | 3.55 | 2.5 | 1.35 | 1.2 | 1.5 | 1.85 | 1.9 |
| 2 | 2.85 | 2.7 | 3.5 | 3.75 | 4.05 | 3.55 | 2.37 | 1.35 | 1.2 | 1.52 | 1.8 | 1.8 |
| 3 | 2.5 | 2.6 | 3.53 | 3.92 | 4.0 | 3.55 | 2.3 | 1.3 | 1.2 | 1.6 | 1.8 | 1.8 |
| 4 | 2.3 | 2.55 | 3.7 | 4.15 | 4.2 | 3.57 | 2.23 | 1.35 | 1.2 | 1.6 | 1.7 | 1.8 |
| 5 | 2.3 | 2.45 | 3.8 | 4.1 | 4.55 | 3.65 | 2.2 | 1.4 | 1.2 | 1.6 | 1.7 | 1.8 |
| 6 | 2.25 | 2.45 | 3.8 | 4.08 | 4.55 | 3.53 | 2.1 | 1.35 | 1.2 | 1.55 | 1.7 | 1.85 |
| 7 | 2.2 | 2.4 | 3.75 | 4.15 | 4.5 | 3.45 | 2.02 | 1.35 | 1.2 | 1.65 | 1.75 | 1.9 |
| 8 | 2.0 | 2.3 | 3.7 | 4.3 | 4.45 | 3.37 | 2.0 | 1.35 | 1.2 | 1.6 | 1.75 | 1.85 |
| 9 | 1.9 | 2.4 | 3.6 | 4.35 | 4.43 | 3.3 | 1.93 | 1.35 | 1.2 | 1.55 | 1.75 | 1.8 |
| 10 | 1.95 | 2.3 | 3.52 | 4.45 | 4.77 | 3.2 | 1.9 | 1.3 | 1.2 | 1.55 | 1.75 | 1.8 |
| 11 | 1.8 | 2.3 | 3.48 | 4.4 | 4.63 | 3.2 | 1.8 | 1.3 | 1.2 | 1.6 | 1.7 | 1.7 |
| 12 | 1.8 | 2.2 | 3.5 | 4.2 | 4.52 | 3.15 | 1.75 | 1.3 | 1.25 | 1.62 | 1.7 | 1.85 |
| 13 | 1.7 | 2.1 | 3.5 | 4.02 | 4.3 | 3.12 | 1.7 | 1.25 | 1.25 | 1.66 | 1.75 | 1.8 |
| 14 | 1.7 | 1.9 | 3.52 | 3.92 | 4.15 | 3.13 | 1.67 | 1.25 | 1.48 | 1.65 | 1.75 | 1.7 |
| 15 | 1.8 | 1.7 | 3.63 | 3.8 | 4.05 | 3.02 | 1.65 | 1.25 | 1.65 | 1.65 | 1.75 | 1.65 |
| 16 | 1.8 | 1.8 | 3.7 | 3.7 | 3.97 | 2.9 | 1.63 | 1.2 | 1.4 | 1.65 | 1.75 | 1.6 |
| 17 | 2.1 | 1.9 | 3.65 | 3.75 | 3.9 | 2.83 | 1.6 | 1.2 | 1.35 | 1.65 | 1.7 | 1.7 |
| 18 | 2.6 | 2.1 | 3.72 | 3.75 | 3.95 | 2.78 | 1.6 | 1.2 | 1.3 | 1.7 | 1.7 | 1.85 |
| 19 | 2.6 | 2.25 | 4.03 | 3.7 | 4.08 | 2.75 | 1.6 | 1.2 | 1.3 | 1.7 | 1.7 | 1.85 |
| 20 | 2.5 | 2.8 | 4.0 | 3.7 | 3.97 | 2.75 | 1.55 | 1.2 | 1.3 | 1.7 | 1.7 | 1.9 |
| 21 | 2.4 | 2.6 | 3.9 | 3.8 | 3.85 | 2.62 | 1.55 | 1.2 | 1.3 | 1.75 | 1.7 | 1.8 |
| 22 | 2.5 | 3.1 | 4.2 | 3.93 | 3.8 | 2.53 | 1.5 | 1.2 | 1.3 | 1.8 | 1.8 | 1.9 |
| 23 | 2.4 | 3.3 | 4.3 | 3.92 | 3.75 | 2.45 | 1.47 | 1.2 | 1.3 | 1.75 | 1.8 | 1.8 |
| 24 | 2.6 | 3.2 | 4.07 | 3.88 | 3.67 | 2.65 | 1.45 | 1.2 | 1.3 | 1.75 | 1.8 | 1.8 |

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*Daily gage height, in feet, of John Day River at McDonald, Oreg., for 1905*—Continued.

| Date. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 3.5 | 3.3 | 4.0 | 3.85 | 3.6 | 2.57 | 1.42 | 1.2 | 1.3 | 1.75 | 1.8 | 1.68 |
| 26 | 3.5 | 3.25 | 4.08 | 3.9 | 3.5 | 2.5 | 1.4 | 1.2 | 1.35 | 1.75 | 1.7 | 1.65 |
| 27 | 3.4 | 3.37 | 4.0 | 4.0 | 3.4 | 2.68 | 1.4 | 1.2 | 1.35 | 1.75 | 1.65 | 1.75 |
| 28 | 3.2 | 3.5 | 4.27 | 4.45 | 3.35 | 2.6 | 1.37 | 1.2 | 1.4 | 1.8 | 1.6 | 1.88 |
| 29 | 3.3 | ..... | 4.1 | 4.17 | 3.43 | 2.6 | 1.35 | 1.2 | 1.4 | 1.85 | 1.7 | 1.9 |
| 30 | 3.2 | ..... | 3.95 | 3.98 | 3.4 | 2.5 | 1.35 | 1.2 | 1.5 | 1.9 | 1.9 | 1.85 |
| 31 | 3.3 | ..... | 3.88 | ..... | 4.05 | ..... | 1.35 | 1.2 | ..... | 1.9 | ..... | 1.8 |

NOTE.—During the frozen period the ice was kept clear for several hundred feet above and below gage.

*Station rating table for John Day River at McDonald, Oreg., from November 14, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.20 | 88 | 2.20 | 750 | 3.10 | 1,798 | 4.00 | 3,280 |
| 1.30 | 128 | 2.30 | 852 | 3.20 | 1,930 | 4.10 | 3,486 |
| 1.40 | 170 | 2.40 | 958 | 3.30 | 2,072 | 4.20 | 3,700 |
| 1.50 | 215 | 2.50 | 1,070 | 3.40 | 2,219 | 4.30 | 3,922 |
| 1.60 | 266 | 2.60 | 1,183 | 3.50 | 2,375 | 4.40 | 4,154 |
| 1.70 | 326 | 2.70 | 1,300 | 3.60 | 2,539 | 4.50 | 4,400 |
| 1.80 | 396 | 2.80 | 1,420 | 3.70 | 2,711 | 4.60 | 4,659 |
| 1.90 | 474 | 2.90 | 1,543 | 3.80 | 2,892 | 4.70 | 4,930 |
| 2.00 | 560 | 3.00 | 1,670 | 3.90 | 3,082 | 4.80 | 5,218 |
| 2.10 | 652 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on 11 discharge measurements made during 1904-5. It is well defined between gage heights 1.25 feet and 4.75 feet.

*Estimated monthly discharge of John Day River at McDonald, Oreg., for 1904 and 1905.*

[Drainage area, 8,000 square miles.]

| Month. | Discharge in second-feet. | | | Total in acre-feet | Run-off. | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | | Second-feet per square mile. | Depth in inches. |
| 1904. | | | | | | |
| November 14-30 | 516 | 326 | 456 | 15,380 | 0.057 | 0.036 |
| December | 569 | 295 | 489 | 30,070 | .061 | .070 |
| 1905. | | | | | | |
| January | 2,375 | 326 | 1,093 | 67,200 | 0.137 | 0.158 |
| February | 2,375 | 326 | 1,181 | 65,590 | .148 | .154 |
| March | 3,922 | 2,296 | 2,921 | 179,600 | .365 | .421 |
| April | 4,275 | 2,711 | 3,296 | 196,100 | .412 | .460 |
| May | 5,130 | 2,145 | 3,395 | 208,700 | .424 | .489 |
| June | 2,624 | 1,014 | 1,705 | 101,500 | .213 | .238 |
| July | 1,070 | 149 | 391 | 24,040 | .049 | .056 |
| August | 170 | 88 | 112 | 6,887 | .014 | .016 |
| September | 295 | 88 | 129 | 7,676 | .016 | .018 |
| October | 474 | 215 | 318 | 19,550 | .040 | .046 |
| November | 474 | 266 | 355 | 21,120 | .044 | .049 |
| December | 516 | 266 | 397 | 24,410 | .050 | .058 |
| The year | 5,130 | 88 | 1,274 | 922,400 | .159 | 2.16 |

NOTE.—No correction made for ice conditions.

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## ROCK CREEK NEAR ARLINGTON, OREG.

Rock Creek drains a high, rolling country containing very little timber. This station was established February 25, 1905. It is located at the highway bridge at Rockville station, Oreg., on the Condon branch of the Oregon Railroad and Navigation Company's line, and is about 6 miles above the mouth of Rock Creek and about 20 miles from Arlington, Oreg.

The channel is straight for 75 feet above and 100 feet below the station. The current is moderate above and sluggish below. The right bank is high and clean. Some water crosses the road at the left bank during very high water. The bed of the stream is composed of sand and gravel and is free from vegetation and permanent. There is but one channel at all stages.

Discharge measurements are made from the upstream side of the single-span wooden bridge. The initial point for soundings is the face of the right abutment.

The elevation of the water surface is determined by measuring down by means of a graduated rod. Between February 25 and August 19, 1905, gage-height observations were taken once each day by W. A. Nugent. The bench mark is the top of a projecting beam from the upstream side of the bridge, at the left bank, marked with black paint; elevation, 15.00 feet above the datum of the gage.

*Discharge measurements of Rock Creek near Arlington, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| February 25 | W. C. Sawyer | 45 | 77 | 2.61 | 6.81 | 201 |
| March 18 | do | 29 | 37 | 1.24 | 5.77 | 46 |
| March 26[a] | J. H. Lewis | 35 | 74 | 2.10 | 6.91 | 155 |
| April 8 | do | 35 | 49 | 1.70 | 6.15 | 83 |
| May 10 | W. C. Sawyer | 30 | 38 | 1.03 | 5.85 | 39 |
| August 17 | do | | | | | .0 |
| October 24 | do | | | | 5.07 | .3 |
| December 5 | R. S. Hall | | | | 5.06 | [b].1 |

[a] Made at different section. [b] Estimated.

*Daily gage height, in feet, of Rock Creek near Arlington, Oreg., for 1905.*

| Day. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. |
|---|---|---|---|---|---|---|---|
| 1 | | 6.2 | 6.25 | 5.3 | 5.8 | 5.3 | 5.0 |
| 2 | | 6.1 | 6.25 | 5.45 | 5.6 | 5.2 | 5.3 |
| 3 | | 6.2 | 6.65 | 5.4 | 5.55 | 5.05 | 5.05 |
| 4 | | 6.15 | 6.45 | 5.45 | 5.4 | 5.0 | 5.0 |
| 5 | | 6.15 | 6.4 | 5.55 | 5.4 | 5.05 | 5.0 |
| 6 | | 6.15 | 6.3 | 5.6 | 5.4 | 5.05 | 5.0 |
| 7 | | 6.0 | 6.15 | 5.6 | 5.4 | 5.05 | 5.0 |
| 8 | | 5.95 | 6.1 | 5.6 | 5.35 | 5.05 | 5.0 |
| 9 | | 5.9 | 6.05 | 5.55 | 5.35 | 5.1 | 5.0 |
| 10 | | 5.8 | 6.1 | 5.85 | 5.3 | 5.1 | 5.0 |
| 11 | | 5.7 | 6.05 | 5.83 | 5.3 | 5.05 | 5.0 |
| 12 | | 5.7 | 5.95 | 5.75 | 5.25 | 5.05 | 5.0 |
| 13 | | 5.65 | 5.85 | 5.7 | 5.25 | 5.05 | 4.95 |
| 14 | | 5.75 | 5.85 | 5.7 | 5.2 | 5.05 | 4.95 |
| 15 | | 5.7 | 5.8 | 5.6 | 5.2 | 5.05 | 4.95 |
| 16 | | 5.7 | 5.8 | 5.55 | 5.1 | 5.0 | 4.95 |
| 17 | | 5.65 | 5.8 | 5.5 | 5.1 | 5.0 | 4.95 |
| 18 | | 5.75 | 5.75 | 5.5 | 5.1 | 5.0 | 5.1 |

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*Daily gage height, in feet, of Rock Creek near Arlington, Oreg., for 1905*—Continued.

| Day. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. |
|---|---|---|---|---|---|---|---|
| 19 | | 6.1 | 5.7 | 5.5 | 5.15 | 5.0 | 5.0 |
| 20 | | 6.1 | 5.7 | 5.45 | 5.05 | 5.0 | ..... |
| 21 | | 6.1 | 5.7 | 5.45 | 5.05 | 5.0 | ..... |
| 22 | | 6.65 | 5.65 | 5.4 | 5.05 | 5.0 | ..... |
| 23 | | 6.4 | 5.7 | 5.4 | 5.05 | 5.0 | ..... |
| 24 | | 6.78 | 5.7 | 5.45 | 5.05 | 5.0 | ..... |
| 25 | 6.8 | 7.0 | 5.6 | 5.45 | 5.05 | 4.95 | ..... |
| 26 | 6.2 | 6.7 | 5.4 | 5.45 | 5.2 | 4.95 | ..... |
| 27 | 6.25 | 7.0 | 5.4 | 5.45 | 5.5 | 4.95 | ..... |
| 28 | 6.15 | 6.6 | 5.45 | 5.4 | 5.35 | 4.95 | ..... |
| 29 | ..... | 6.45 | 5.4 | 5.35 | 5.3 | 5.0 | ..... |
| 30 | ..... | 6.35 | 5.3 | 5.35 | 5.35 | 5.0 | ..... |
| 31 | ..... | 6.2 | ..... | 5.3 | ..... | 5.0 | ..... |

*Station rating table for Rock Creek near Arlington, Oreg., from February 25 to August 19, 1905*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 5.00 | 0 | 5.60 | 28 | 6.10 | 76 | 6.60 | 165 |
| 5.10 | 2 | 5.70 | 36 | 6.20 | 88 | 6.70 | 178 |
| 5.20 | 6 | 5.80 | 45 | 6.30 | 102 | 6.80 | 202 |
| 5.30 | 10 | 5.90 | 54 | 6.40 | 118 | 6.90 | 228 |
| 5.40 | 15 | 6.00 | 64 | 6.50 | 136 | 7.00 | 256 |
| 5.50 | 21 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on discharge measurements made during 1905. It is fairly well defined.

*Estimated monthly discharge of Rock Creek near Arlington, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| March | 256 | 32 | 93.2 | 5,731 |
| April | 167 | 10 | 57.5 | 3,422 |
| May | 50 | 10 | 22.7 | 1,396 |
| June | 45 | 1 | 10.2 | 607 |
| July | 10 | 0 | .97 | 60 |

## DESCHUTES RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Deschutes River rises on the eastern slopes of the Cascade Mountains, in Klamath County, Oreg., and flows northward, entering Columbia River at Deschutes, Oreg. Its principal tributaries are West Fork, Squaw Creek, and Spring River from the west, and Crooked River and Willow and Trout creeks from the east.

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## DESCHUTES RIVER NEAR BEND, OREG.

This station was established December 22, 1904, by W. C. Sawyer. It is located at the wagon bridge known as Sizemore's bridge, 1¼ miles south of Bend, Oreg.

The channel is straight for 300 feet above and below the station. The current is swift and both banks are high. The left bank is subject to overflow at extreme high water. The bed of the stream is composed of rock and gravel and is free from vegetation and permanent. There is but one channel at all stages.

Discharge measurements are made from the downstream side of the bridge. The initial point for soundings is a point marked with black paint at the west end of the bridge, downstream side.

A staff gage is fastened vertically to the sixteenth bent of the bridge, 335 feet from the initial point for soundings. During 1905 the gage was read once each day by Dr. W. S. Nichol, who was paid by the Deschutes Irrigation and Power Company. The bench mark is a copper bolt cemented in a large bowlder near the edge of the water, about 100 feet above the east end of the bridge; elevation, 5.20 feet above the datum of the gage.

A description of this station, with gage heights and discharge data, is contained in Water-Supply Paper No. 135, United States Geological Survey, page 269.

*Discharge measurements of Deschutes River near Bend, Oreg., in 1905.*

| Date | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| February 7 | I. Landes | 375 | 828 | 2.54 | 2.00 | 2,100 |
| March 6 | do | 375 | 828 | 2.63 | 1.95 | 2,180 |
| April 20 | do | 375 | 797 | 2.57 | 1.90 | 2,050 |
| May 21 | do | 375 | 706 | 2.67 | 1.69 | 1,887 |
| August 10 | do | 375 | 654 | 2.43 | 1.55 | 1,590 |
| September 22 | do | 370 | 623 | 2.43 | 1.46 | 1,516 |
| October 27 | do | 370 | 634 | 2.35 | 1.50 | 1,490 |
| November 15 | do | 370 | 600 | 2.24 | 1.40 | 1,346 |
| December 7 | do | 370 | 597 | 2.02 | 1.40 | 1,209 |

*Daily gage height, in feet, of Deschutes River near Bend, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.0 | 2.1 | 1.9 | 2.0 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 |
| 2 | 2.0 | 2.1 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 |
| 3 | 2.0 | 2.1 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 |
| 4 | 2.0 | 3.1 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |
| 5 | 2.0 | 2.1 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |
| 6 | 2.0 | 2.1 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |
| 7 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |
| 8 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.4 | 1.4 |
| 9 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.4 | 1.4 |
| 10 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.4 | 1.4 |
| 11 | 2.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.4 | 1.4 |
| 12 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.4 | 1.4 |
| 13 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.4 | 1.4 |
| 14 | 1.9 | 2.0 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 |
| 15 | 1.9 | 2.1 | 1.9 | 1.9 | 1.9 | 1.7 | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 |
| 16 | 1.9 | 2.0 | 1.9 | 1.9 | 2.0 | 1.7 | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 |
| 17 | 2.0 | 1.8 | 1.9 | 1.9 | 2.0 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |
| 18 | 2.0 | 1.8 | 1.9 | 1.9 | 1.9 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |

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*Daily gage height, in feet, of Deschutes River near Bend, Oreg., for 1905*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 2.0 | 1.8 | 1.9 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |
| 20 | 2.0 | 1.8 | 2.0 | 1.9 | 1.7 | 1.7 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |
| 21 | 2.0 | 1.9 | 2.0 | 1.9 | 1.7 | *1.7 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |
| 22 | 2.0 | 1.9 | 2.0 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.3 |
| 23 | 2.0 | 1.9 | 2.0 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.3 |
| 24 | 2.0 | 1.9 | 2.0 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |
| 25 | 2.0 | 1.9 | 2.0 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| 26 | 2.0 | 1.9 | 2.0 | 1.8 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| 27 | 2.1 | 1.9 | 2.0 | 1.8 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| 28 | 2.1 | 1.9 | 2.0 | 1.8 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 | 1.5 |
| 29 | 2.2 | ..... | 2.0 | 1.8 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | ..... | 1.4 | 1.5 |
| 30 | 2.3 | ..... | 2.0 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | ..... | 1.4 | 1.5 |
| 31 | 2.1 | ..... | 2.0 | ..... | 1.7 | ..... | 1.6 | 1.5 | ..... | ..... | ..... | 1.5 |

*Station rating table for Deschutes River near Bend, Oreg., from December 22, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet* |
| 1.30 | 1,220 | 1.60 | 1,630 | 1.90 | 2,075 | 2.20 | 2,535 |
| 1.40 | 1,350 | 1.70 | 1,775 | 2.00 | 2,225 | 2.30 | 2,095 |
| 1.50 | 1,490 | 1.80 | 1,925 | 2.10 | 2,375 | | |

The above table is applicable only for open-channel conditions. It is based on 11 discharge measurements made during 1904–5. It is fairly well defined.

*Estimated monthly discharge of Deschutes River near Bend, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 2,695 | 2,075 | 2,240 | 137,700 |
| February | 2,375 | 1,925 | 2,161 | 120,000 |
| March | 2,225 | 2,075 | 2,133 | 131,200 |
| April | 2,225 | 1,925 | 2,060 | 122,600 |
| May | 2,225 | 1,775 | 1,959 | 120,500 |
| June | 1,775 | 1,630 | 1,712 | 101,900 |
| July | 1,630 | 1,630 | 1,630 | 100,200 |
| August | 1,630 | 1,490 | 1,531 | 94,140 |
| September | 1,490 | 1,490 | 1,490 | 88,660 |
| October[a] | 1,490 | 1,490 | 1,490 | 91,620 |
| November | 1,490 | 1,350 | 1,434 | 85,330 |
| December | 1,490 | 1,220 | 1,373 | 84,420 |
| The year | 2,695 | 1,220 | 1,768 | 1,278,000 |

[a] Discharge interpolated October 29–31.

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## EAST FORK OF DESCHUTES RIVER AT ODELL, OREG.

This station was established December 25, 1904, by W. C. Sawyer. It is located at the county wagon bridge at Odell, Oreg. The drainage basin is high, composed of a pumice-stone soil, and covered largely with a growth of black pines.

The current is swift and the channel curved with both banks low and clean. The left bank is liable to overflow at high water. The bed of the stream is composed of gravel and sand and is free from vegetation and permanent. There are two or more channels at the bridge during high water and one at low and ordinary stages. There is but one channel at all stages at the foot log.

Discharge measurements are made from the bridge at all ordinary stages. At extreme high water a foot log below the bridge is used. The initial point for soundings at the bridge is a 10-penny nail driven into a log at the south end of the bridge, downstream side. The initial point at the foot log is a 10-penny nail driven into the north end of the foot log.

A staff gage is fastened to logs projecting from a milk house belonging to the observer. During 1905 the gage was read once each day by Charles Graves. The bench mark is a 60-penny nail in the base of a jack-pine tree used for a gatepost in the fence of Mr. Graves's yard; elevation, 7.87 feet above the datum of the gage.

A description of this station, with gage heights, is contained in Water-Supply Paper No. 135, pages 269–270.

*Discharge measurements of East Fork of Deschutes River at Odell, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| January 31 | I. Landes | 24 | 31.0 | 2.03 | 2.50 | 63 |
| March 9 | do | 24 | 35.7 | 1.30 | 2.45 | 56 |
| April 26 | do | 24 | 40.0 | 1.93 | 2.65 | 77 |
| April 29 | do | 25 | 39.2 | 1.89 | 2.64 | 74 |
| June 25 | do | 22 | 35.0 | 1.57 | 2.45 | 55 |
| June 25 | do | 22 | 35.0 | 1.54 | 2.45 | 54 |
| August 4 | H. W. King | 24 | 29.2 | 1.04 | 2.18 | 30.3 |
| October 6 | I. Landes | 22 | 28.1 | 1.03 | 2.15 | 29.1 |
| October 30 | do | 22 | 24.0 | 1.30 | 2.18 | 31.1 |

*Daily gage height, in feet, of East Fork of Deschutes River at Odell, Oreg., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.5 | 2.4 | 2.5 | 2.5 | 2.7 | 2.6 | 2.35 | 2.1 | 2.1 | 2.18 | 2.29 | 2.3 |
| 2 | 2.65 | 2.5 | 2.5 | 2.5 | 2.65 | 2.6 | 2.3 | 2.15 | 2.1 | 2.18 | 2.05 | 2.2 |
| 3 | 2.6 | 2.7 | 2.5 | 2.5 | 2.65 | 2.6 | 2.3 | 2.15 | 2.1 | 2.15 | 1.95 | 2.2 |
| 4 | 2.65 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.65 | 2.15 | 2.1 | 2.15 | 2.18 | 2.2 |
| 5 | 2.65 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.65 | 2.15 | 2.1 | 2.15 | 2.12 | 2.18 |
| 6 | 2.6 | 2.5 | 2.5 | 2.6 | 2.6 | 2.65 | 2.65 | 2.2 | 2.1 | 2.15 | 2.0 | 2.18 |
| 7 | 2.6 | 2.3 | 2.5 | 2.55 | 2.6 | 2.65 | 2.2 | 2.25 | 2.1 | 2.25 | 2.0 | 2.18 |
| 8 | 2.5 | 2.6 | 2.5 | 2.55 | 2.7 | 2.6 | 2.1 | 2.15 | 2.1 | 2.3 | 2.02 | 2.2 |
| 9 | 2.6 | 2.65 | 2.5 | 2.55 | 2.8 | 2.6 | 2.2 | 2.18 | 2.1 | 2.3 | 2.05 | 2.2 |
| 10 | 2.5 | 2.65 | 2.5 | 2.5 | 2.7 | 2.65 | 2.15 | 2.18 | 2.1 | 2.25 | 2.05 | 2.18 |
| 11 | 2.5 | 2.58 | 2.5 | 2.5 | 2.7 | 2.6 | 2.2 | 2.2 | 2.1 | 2.2 | 2.03 | 2.18 |
| 12 | 2.6 | 2.6 | 2.5 | 2.5 | 2.65 | 2.6 | 2.2 | 2.15 | 2.1 | 2.2 | 1.95 | 2.18 |
| 13 | 2.65 | 2.7 | 2.55 | 2.5 | 2.6 | 2.6 | 2.2 | 2.15 | 2.1 | 2.18 | 2.25 | 2.2 |
| 14 | 2.7 | 2.7 | 2.55 | 2.5 | 2.6 | 2.6 | 2.2 | 2.15 | 2.1 | 2.18 | 2.3 | 2.4 |
| 15 | 2.9 | 2.8 | 2.5 | 2.55 | 2.6 | 2.6 | 2.25 | 2.18 | 2.1 | 2.18 | 2.2 | 2.4 |

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*Daily gage height, in feet, of East Fork of Deschutes River at Odell, Oreg., for 1905*—Cont'd.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 3.1 | 2.7 | 2.5 | 2.55 | 2.6 | 2.55 | 2.2 | 2.18 | 2.1 | 2.2 | 2.2 | 2.4 |
| 17 | 2.9 | 2.7 | 2.5 | 2.5 | 2.7 | 2.5 | 2.25 | 2.13 | 2.1 | 2.2 | 2.1 | 2.4 |
| 18 | 2.8 | 2.8 | 2.55 | 2.7 | 2.7 | 2.5 | 2.2 | 2.15 | 2.1 | 2.2 | 2.1 | 2.3 |
| 19 | 2.7 | 2.8 | 2.5 | 2.5 | 2.7 | 2.5 | 2.2 | 2.15 | 2.1 | 2.2 | 2.1 | 2.3 |
| 20 | 2.7 | 2.9 | 2.55 | 2.5 | 2.7 | 2.5 | 2.2 | 2.13 | 2.1 | 2.18 | 2.1 | 2.3 |
| 21 | 2.7 | 2.8 | 2.6 | 2.52 | 2.7 | 2.5 | 2.2 | 2.12 | 2.1 | 2.18 | 2.15 | 1.9 |
| 22 | 2.7 | 2.7 | 2.65 | 2.5 | 2.65 | 2.4 | 2.15 | 2.11 | 2.1 | 2.18 | 2.0 | 2.9 |
| 23 | 2.7 | 2.7 | 2.55 | 2.55 | 2.6 | 2.45 | 2.15 | 2.11 | 2.1 | 2.18 | 1.9 | 2.6 |
| 24 | 2.7 | 2.7 | 2.6 | 2.55 | 2.6 | 2.45 | 2.15 | 2.11 | 2.1 | 2.18 | 1.8 | 2.9 |
| 25 | 2.7 | 2.6 | 2.65 | 2.55 | 2.6 | 2.4 | 2.15 | 2.11 | 2.1 | 2.18 | 1.85 | 2.9 |
| 26 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.4 | 2.1 | 2.11 | 2.1 | 2.2 | 1.9 | 2.9 |
| 27 | 2.6 | 2.5 | 2.65 | 2.7 | 2.6 | 2.4 | 2.1 | 2.11 | 2.13 | 2.2 | 2.1 | 2.9 |
| 28 | 2.6 | 2.5 | 2.6 | 2.7 | 2.6 | 2.4 | 2.1 | 2.11 | 2.15 | 2.2 | 2.1 | 2.0 |
| 29 | 2.7 | ..... | 2.5 | 2.7 | 2.6 | 2.35 | 2.0 | 2.11 | 2.15 | 2.19 | 2.1 | 1.9 |
| 30 | 2.5 | ..... | 2.8 | 2.65 | 2.6 | 2.35 | 2.1 | 2.11 | 2.18 | 2.18 | 2.1 | 1.9 |
| 31 | 2.5 | ..... | 2.5 | ..... | 2.6 | ..... | 2.1 | 2.11 | ..... | 2.18 | ..... | 1.8 |

NOTE.—Ice conditions, January 10 to February 28.

*Station rating table for East Fork of Deschutes River at Odell, Oreg., from December 26, 1904, to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.80 | 10 | 2.20 | 32 | 2.60 | 70 | 2.90 | 104 |
| 1.90 | 14 | 2.30 | 41 | 2.70 | 81 | 3.00 | 117 |
| 2.00 | 19 | 2.40 | 50 | 2.80 | 92 | 3.10 | 131 |
| 2.10 | 25 | 2.50 | 60 | | | | |

The above table is applicable only for open-channel conditions. It is based on nine discharge measurements made during 1905. It is well defined between gage heights 2.1 feet and 2.7 feet.

*Estimated monthly discharge of East Fork of Deschutes River at Odell, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| January | 131 | 60 | 76.6 | 4,710 |
| February | 104 | 41 | 74.0 | 4,110 |
| March | 92 | 60 | 64.7 | 3,978 |
| April | 81 | 60 | 65.4 | 3,892 |
| May | 92 | 70 | 74.7 | 4,593 |
| June | 76 | 46 | 62.8 | 3,737 |
| July | 76 | 19 | 35.1 | 2,158 |
| August | 36 | 25 | 28.0 | 1,722 |
| September | 31 | 25 | 25.5 | 1,517 |
| October | 41 | 28 | 31.9 | 1,962 |
| November | 41 | 10 | 23.6 | 1,404 |
| December | 104 | 10 | 45.6 | 2,804 |
| The year | 131 | 10 | 50.7 | 36,590 |

NOTE.—No correction made for ice conditions.

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## DESCHUTES RIVER NEAR LAVA, OREG.

This station was established February 17, 1905. It is located about 1 mile north of Lava, Oreg. The river has its source in Crescent Lake, receives the waters of East Fork about 30 miles above the station, and joins West Fork, which is larger and is locally known as Big River, a short distance below the station. A considerable portion of the basin is timbered.

The channel is straight for 200 feet above and 100 feet below the station. The current is swift. Both banks are high and clean. The bed of the stream is composed of clay and is free from vegetation and permanent. There is but one channel at all stages.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is the center of the mud sill under the shear legs of the cable support on the east bank of the river.

An inclined staff gage is fastened to the right bank. During 1905 the gage was read once each day by Mrs. C. B. Allen. The bench mark is a copper bolt set in the base of a large jack-pine tree about 75 feet below the cable and near the east end of the wagon bridge; elevation, 11.38 feet above the datum of the gage.

*Discharge measurements of Deschutes River near Lava, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| March 2 | I. Landes | 82 | 195 | 1.47 | 6.44 | 286 |
| April 24 | do | 82 | 183 | 1.52 | 6.20 | 277 |
| May 23 | do | 82 | 182 | 1.48 | 6.34 | 270 |
| June 23 | do | 82 | 169 | 1.17 | 6.00 | 198 |
| June 23 | do | 82 | 170 | 1.22 | 6.00 | 208 |
| August 9 | do | 79 | 125 | .83 | 5.29 | 104 |
| November 18 | do | 51 | 110 | .90 | 5.00 | 100 |
| December 8 | do | 51 | 107 | .92 | 5.08 | [a]107 |

[a] Narrow strip of ice along each bank.

*Daily gage height, in feet, of Deschutes River near Lava, Oreg., for 1905.*

| Day. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 6.45 | 6.55 | 6.35 | 6.3 | 5.95 | 5.4 | 5.05 | 5.15 | 5.15 | 5.1 |
| 2 | | 6.45 | 6.55 | 6.4 | 6.3 | 5.85 | 5.4 | 5.05 | 5.2 | 5.1 | 5.1 |
| 3 | | 6.45 | 6.55 | 6.45 | 6.4 | 5.85 | 5.4 | 5.05 | 5.1 | 5.05 | 5.1 |
| 4 | | 6.5 | 6.55 | 6.5 | 6.45 | 5.8 | 5.3 | 5.0 | 5.1 | 5.05 | 5.1 |
| 5 | | 6.5 | 6.5 | 6.4 | 6.4 | 5.8 | 5.3 | 5.0 | 5.1 | 5.05 | 5.0 |
| 6 | | 6.5 | 6.5 | 6.35 | 6.4 | 5.75 | 5.3 | 5.0 | 5.1 | 5.0 | 5.0 |
| 7 | | 6.5 | 6.45 | 6.3 | 6.4 | 5.7 | 5.3 | 5.0 | 5.15 | 5.0 | 4.95 |
| 8 | | 6.5 | 6.45 | 6.4 | 6.35 | 5.7 | 5.3 | 5.0 | 5.2 | 5.0 | 5.15 |
| 9 | | 6.45 | 6.45 | 6.45 | 6.3 | 5.65 | 5.3 | 5.0 | 5.3 | 5.0 | 4.9 |
| 10 | | 6.4 | 6.45 | 6.5 | 6.3 | 5.6 | 5.3 | 5.0 | 5.3 | 5.0 | 5.0 |
| 11 | | 6.4 | 6.4 | 6.55 | 6.25 | 5.55 | 5.3 | 5.0 | 5.2 | 5.0 | 5.0 |
| 12 | | 6.4 | 6.3 | 6.55 | 6.25 | 5.55 | 5.3 | 5.0 | 5.2 | 5.0 | 5.0 |
| 13 | | 6.4 | 6.3 | 6.5 | 6.3 | 5.55 | 5.25 | 5.05 | 5.15 | 5.0 | 5.0 |
| 14 | | 6.4 | 6.3 | 6.4 | 6.2 | 5.55 | 5.2 | 5.05 | 5.15 | 4.9 | 5.0 |
| 15 | | 6.45 | 6.3 | 6.35 | 6.2 | 5.5 | 5.2 | 5.05 | 5.15 | 4.85 | 5.05 |
| 16 | | 6.5 | 6.35 | 6.4 | 6.15 | 5.5 | 5.2 | 5.05 | 5.2 | 4.9 | 5.1 |
| 17 | 6.3 | 6.5 | 6.35 | 6.3 | 6.15 | 5.5 | 5.2 | 5.05 | 5.2 | 5.0 | 5.1 |
| 18 | 6.32 | 6.5 | 6.35 | 6.3 | 6.1 | 5.5 | 5.2 | 5.05 | 5.25 | 5.0 | 5.1 |
| 19 | 6.4 | 6.5 | 6.35 | 6.3 | 6.1 | 5.5 | 5.2 | 5.05 | 5.2 | 5.1 | 5.15 |

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*Daily gage height, in feet, of Deschutes River near Lava, Oreg., for 1905*—Continued.

| Day. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 6.7 | 6.55 | 6.3 | 6.3 | 6.1 | 5.45 | 5.15 | 5.0 | 5.2 | 5.1 | 5.2 |
| 21 | 6.75 | 6.65 | 6.3 | 6.3 | 6.05 | 5.4 | 5.15 | 5.0 | 5.2 | 5.1 | 5.3 |
| 22 | 6.6 | 6.75 | 6.25 | 6.35 | 6.0 | 5.4 | 5.1 | 5.0 | 5.2 | 5.0 | 5.2 |
| 23 | 6.65 | 6.75 | 6.25 | 6.35 | 6.0 | 5.4 | 5.1 | 5.0 | 5.15 | 5.0 | 5.05 |
| 24 | 6.4 | 6.7 | 6.2 | 6.3 | 6.0 | 5.4 | 5.1 | 5.0 | 5.15 | 5.0 | 5.15 |
| 25 | 6.5 | 6.7 | 6.2 | 6.25 | 6.05 | 5.4 | 5.1 | 5.0 | 5.15 | 5.0 | 5.15 |
| 26 | 6.5 | 6.75 | 6.2 | 6.35 | 6.0 | 5.35 | 5.1 | 5.0 | 5.15 | 5.0 | 5.25 |
| 27 | 6.45 | 6.75 | 6.2 | 6.3 | 6.1 | 5.3 | 5.1 | 5.0 | 5.15 | 5.1 | 5.3 |
| 28 | 6.4 | 6.8 | 6.2 | 6.35 | 6.05 | 5.3 | 5.1 | 5.05 | 5.15 | 5.1 | 5.3 |
| 29 | ..... | 6.75 | 6.25 | 6.35 | 6.0 | 5.3 | 5.05 | 5.05 | 5.15 | 5.0 | 5.3 |
| 30 | ..... | 6.65 | 6.3 | 6.35 | 6.0 | 5.3 | 5.05 | 5.1 | 5.15 | 5.0 | 5.3 |
| 31 | ..... | 6.55 | ..... | 6.3 | ..... | 5.3 | 5.05 | ..... | 5.15 | ..... | 5.3 |

*Station rating table for Deschutes River near Lava, Oreg., from January 17 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 4.80 | 76 | 5.40 | 125 | 5.90 | 188 | 6.40 | 283 |
| 4.90 | 82 | 5.50 | 135 | 6.00 | 205 | 6.50 | 305 |
| 5.00 | 89 | 5.60 | 147 | 6.10 | 223 | 6.60 | 329 |
| 5.10 | 97 | 5.70 | 160 | 6.20 | 242 | 6.70 | 355 |
| 5.20 | 106 | 5.80 | 173 | 6.30 | 262 | 6.80 | 382 |
| 5.30 | 115 | | | | | | |

The above table is applicable only for open-channel conditions. It is based on eight discharge measurements made during 1905. It is well defined between gage heights 5 feet and 6.5 feet.

*Estimated monthly discharge of Deschutes River near Lava, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| February 17-28 | 368 | 262 | 306 | 7,283 |
| March | 382 | 283 | 319 | 19,620 |
| April | 317 | 242 | 274 | 16,300 |
| May | 317 | 252 | 278 | 17,090 |
| June | 294 | 205 | 241 | 14,340 |
| July | 196 | 115 | 141 | 8,670 |
| August | 125 | 93 | 107 | 6,579 |
| September | 97 | 89 | 90.9 | 5,409 |
| October | 115 | 97 | 100 | 6,149 |
| November | 102 | 79 | 90.6 | 5,391 |
| December | 115 | 82 | 99.2 | 6,100 |
| The period | | | | 112,900 |

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## WEST FORK OF DESCHUTES RIVER NEAR LAVA, OREG.

This station was established February 20, 1905. It is located about 1½ miles west of Lava, Oreg. This branch of the river rises in five small lakes in a high, timbered country, and as a consequence has a very uniform flow.

The channel is slightly curved and the current is swift. Both banks are low, wooded, and not liable to overflow. The bed of the stream is composed of gravel and is free from vegetation and permanent. There is but one channel at all stages.

Discharge measurements are made by means of a cable and car. The initial point for soundings is the center of the mud sill under the shear legs of the cable support on the north bank of the river, and is marked with a brass nail.

An inclined staff gage is set on the right bank. During 1905 the gage was read once each week by David Hill. The bench mark is a 60-penny nail driven into the base of a large yellow pine near the gage; elevation, 19.33 feet above the datum of the gage.

*Discharge measurements of West Fork of Deschutes River near Lava, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| March 3 | I. Landes | 101 | 544 | 2.10 | 8.89 | 1,144 |
| April 25 | do | 100 | 517 | 2.09 | 8.59 | 1,081 |
| May 23 | do | 101 | 520 | 2.05 | 8.60 | 1,064 |
| June 23 | do | 101 | 499 | 2.07 | 8.44 | 1,033 |
| August 9 | do | 101 | 482 | 2.06 | 8.24 | 993 |
| October 8 | do | 101 | 472 | 2.09 | 8.20 | 986 |
| October 28 | do | 101 | 456 | 2.03 | 8.01 | 926 |
| November 17 | do | 100 | 444 | 2.06 | 7.87 | 917 |
| December 9 | do | 99 | 443 | 1.96 | 7.74 | 870 |
| December 27 | do | 127 | 446 | 2.02 | 7.77 | 903 |
| December 27 | do | 99 | 446 | 2.02 | 7.77 | 904 |

*Daily gage height, in feet, of West Fork of Deschutes River near Lava, Oreg., for 1905.*

| Day. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 8.9 | 8.8 | | | | | | | | |
| 2 | | 8.9 | 8.8 | 8.65 | | | | 8.15 | | | 7.8 |
| 3 | | 8.9 | 8.77 | | | 8.4 | | | | | |
| 4 | | 8.9 | 8.7 | | | | | | | 7.95 | |
| 5 | | 8.93 | 8.7 | | 8.6 | | | | | | |
| 6 | | 8.95 | | | | | | | | | |
| 7 | | 8.95 | 8.7 | | | | 8.2 | | 8.2 | | |
| 8 | | 8.92 | | | | | | | | | |
| 9 | | 8.9 | | 8.7 | | | | 8.25 | | | 7.7 |
| 10 | | 8.9 | | | | 8.3 | | | | | |
| 11 | | 8.9 | 8.6 | | | | | | | 7.9 | |
| 12 | | 8.85 | | | 8.5 | | | | | | |
| 13 | | 8.8 | | | | | 8.2 | | | | |
| 14 | | 8.8 | | | | | | | 8.05 | | |
| 15 | | 8.8 | | | | | | | | | |
| 16 | | 8.83 | | 8.6 | | | | 8.01 | | | 7.8 |
| 17 | | 8.8 | | | | 8.3 | | | | 7.9 | |
| 18 | | 8.8 | 8.6 | | | | | | | | 7.75 |
| 19 | | 8.82 | | | 8.45 | | | | | | |
| 20 | 8.8 | 8.82 | | 8.6 | | | 8.2 | | | | |

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*Daily gage height, in feet, of West Fork of Deschutes River near Lava, Oreg., in 1905—Con.*

| Day. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 8.8 | 8.98 | ..... | ..... | ..... | ..... | ..... | ..... | 8.05 | ..... | 7.7 |
| 22 | 8.8 | 8.98 | ..... | 8.6 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 23 | 8.85 | 8.9 | ..... | ..... | ..... | ..... | ..... | 8.01 | ..... | ..... | 8.0 |
| 24 | 8.9 | 8.92 | ..... | ..... | ..... | 8.3 | ..... | ..... | ..... | ..... | ..... |
| 25 | 8.87 | 8.9 | 8.6 | ..... | ..... | ..... | ..... | ..... | ..... | 7.8 | 7.7 |
| 26 | 8.85 | 8.92 | ..... | ..... | 8.45 | ..... | 8.2 | ..... | ..... | ..... | ..... |
| 27 | 8.88 | 8.95 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 28 | 8.87 | 8.88 | ..... | ..... | ..... | ..... | ..... | ..... | 8.0 | ..... | 7.65 |
| 29 | ..... | 8.9 | ..... | 8.6 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 30 | ..... | 8.8 | ..... | ..... | ..... | ..... | ..... | 8.02 | ..... | ..... | 7.8 |
| 31 | ..... | 8.72 | ..... | ..... | ..... | 8.25 | ..... | ..... | ..... | ..... | ..... |

*Station rating table for West Fork of Deschutes River near Lava, Oreg., from February 20 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 7.60 | 867 | 8.00 | 942 | 8.40 | 1,027 | 8.80 | 1,123 |
| 7.70 | 883 | 8.10 | 963 | 8.50 | 1,050 | 8.90 | 1,148 |
| 7.80 | 902 | 8.20 | 984 | 8.60 | 1,074 | 9.00 | 1,173 |
| 7.90 | 922 | 8.30 | 1,005 | 8.70 | 1,098 | | |

The above table is applicable only for open-channel conditions. It is based on 11 discharge measurements made during 1905. It is well defined between gage heights 7.7 feet and 8.9 feet.

*Estimated monthly discharge of West Fork of Deschutes River near Lava, Oreg., for 1905.*

| Month. | Discharge in second-feet | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| February 20–28 | 1,148 | 1,123 | 1,135 | 20,260 |
| March | 1,168 | 1,103 | 1,142 | 70,220 |
| April | 1,123 | 1,074 | 1,083 | 64,440 |
| May | 1,098 | 1,074 | 1,081 | 66,470 |
| June | 1,074 | 1,038 | 1,050 | 62,480 |
| July | 1,027 | 994 | 1,007 | 61,920 |
| August | 984 | 984 | 984 | 60,500 |
| September | 994 | 944 | 961 | 57,180 |
| October | 984 | 942 | 958 | 58,900 |
| November | 932 | 902 | 920 | 54,740 |
| December | 942 | 875 | 895 | 55,030 |
| The period | ..... | ..... | ..... | 632,100 |

NOTE.—Owing to the steady flow of the river the mean discharge for the days in each month when the gage height was recorded has been taken as the monthly mean.

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## CANALS IN DESCHUTES RIVER VALLEY, OREGON.

### FINDLEY'S DITCH NEAR ROSLAND, OREG.

May 24, 1905, a discharge measurement made of this ditch by Ivan Landes gave a discharge of 3.9 second-feet.

### CENTRAL OREGON CANAL NEAR BEND, OREG.

The gage on the Central Oregon canal is vertical and attached to the south side of the flume opposite station 88 on the Pilot Butte canal. The zero of the gage is the bottom of the flume. Measurements were made in the flume. The gage was read during a portion of the year by G. A. Wilson and Z. T. Gideon.

*Discharge measurements of Central Oregon canal near Bend, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| May 22 | Ivan Landes | 13.2 | 15.8 | 4.40 | 1.20 | 69.5 |
| June 22 | do | 13.3 | 12.0 | 3.62 | .90 | 43.4 |
| August 10 | do | 13.3 | 7.98 | 2.71 | .60 | 21.6 |
| September 22 | do | 13.3 | 14.8 | 3.70 | 1.11 | 54.8 |
| November 16 | do | 13.3 | 15.8 | 3.74 | 1.19 | 59.2 |

*Daily gage height, in feet, of Central Oregon canal near Bend, Oreg., for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | 0.98 | 0.0 | 0.6 | 0.75 | 1.15 | 1.22 | 1.3 |
| 2 | | | | .95 | 1.0 | .0 | .7 | .58 | 1.05 | 1.3 |
| 3 | | | | .95 | .85 | .7 | .7 | .82 | 1.12 | 1.3 |
| 4 | | | | 1.0 | .0 | .7 | .8 | .0 | 1.12 | 1.3 |
| 5 | | | | .95 | .0 | .7 | .78 | .42 | 1.22 | 1.4 |
| 6 | | | | 1.15 | .0 | .7 | 1.1 | .85 | 1.22 | 1.3 |
| 7 | | | | .82 | .0 | .7 | 1.08 | .95 | 1.2 | 1.3 |
| 8 | | | | .32 | .0 | .7 | .78 | 1.05 | 1.1 | 1.4 |
| 9 | | | | .3 | .7 | .7 | .7 | .52 | 1.2 | 1.3 |
| 10 | | | | .45 | .83 | .7 | .65 | .85 | 1.25 | 1.3 |
| 11 | 0.52 | | | .82 | .75 | .7 | .68 | .85 | 1.25 | 1.4 |
| 12 | .52 | | | .85 | .98 | .7 | .65 | 1.15 | 1.25 | 1.4 |
| 13 | .52 | | | 1.0 | .9 | .7 | .7 | 1.15 | 1.25 | 1.4 |
| 14 | .0 | | | 1.0 | .7 | .7 | 1.2 | 1.2 | 1.25 | .9 |
| 15 | .0 | | | 1.3 | .0 | .0 | 1.2 | 1.2 | 1.25 | .9 |
| 16 | .65 | | | .82 | .7 | .7 | 1.25 | 1.0 | 1.25 | 1.4 |
| 17 | .65 | | | .8 | .6 | .7 | 1.25 | 1.0 | 1.2 | 1.5 |
| 18 | | | | .95 | .82 | .0 | 1.0 | 1.0 | 1.22 | 1.4 |
| 19 | | | | .95 | .3 | .7 | 1.0 | 1.0 | 1.3 | 1.4 |
| 20 | | | | .0 | .7 | .62 | 1.0 | 1.0 | 1.3 | 1.4 |
| 21 | | | | .0 | .7 | .52 | 1.1 | 1.0 | 1.32 | 1.4 |
| 22 | | | | .85 | .0 | .55 | 1.15 | 1.0 | 1.35 | 1.1 |
| 23 | | | | .85 | .7 | .52 | 1.12 | 1.0 | 1.35 | .4 |
| 24 | | | | .85 | .7 | .55 | 1.1 | 1.1 | .62 | .0 |
| 25 | | | | .85 | .7 | .9 | .55 | 1.1 | .48 | .0 |
| 26 | | | | .85 | .0 | 1.0 | .65 | 1.27 | 1.1 | .0 |
| 27 | | | | .85 | .35 | .85 | .95 | .1 | 1.3 | .0 |
| 28 | | | | .92 | .6 | .9 | .55 | 1.12 | 1.3 | .0 |
| 29 | | | | .85 | .0 | .9 | 1.15 | 1.05 | 1.3 | .0 |
| 30 | | | | .85 | .6 | .9 | 1.12 | 1.15 | 1.38 | .0 |
| 31 | | | | | .6 | .9 | | 1.3 | | .0 |

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*Station rating table for Central Oregon canal near Bend, Oreg., for 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 0.00 | 0 | 0.70 | 28 | 1.40 | 84 | 2.00 | 153 |
| .10 | 2 | .80 | 34 | 1.50 | 94 | 2.10 | 166 |
| .20 | 5 | .90 | 41 | 1.60 | 105 | 2.20 | 180 |
| .30 | 8 | 1.00 | 48 | 1.70 | 116 | 2.30 | 194 |
| .40 | 12 | 1.10 | 56 | 1.80 | 128 | 2.40 | 209 |
| .50 | 17 | 1.20 | 65 | 1.90 | 140 | 2.50 | 224 |
| .60 | 22 | 1.30 | 74 | | | | |

The above table is applicable only for open-channel conditions. It is based on five discharge measurements made during 1905. It is fairly well defined.

*Estimated monthly discharge of Central Oregon canal near Bend, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| March (7 days) | 25 | 0 | 14.9 | 207 |
| June | 74 | 0 | 36.6 | 2,178 |
| July | 48 | 0 | 19.5 | 1,199 |
| August | 48 | 0 | 26.8 | 1,648 |
| September | 70 | 20 | 43.4 | 2,582 |
| October | 105 | 0 | 45.9 | 2,822 |
| November | 82 | 16 | 65.6 | 3,904 |
| December | 94 | 0 | 54.8 | 3,370 |
| The period | | | | 17,900 |

## PILOT BUTTE CANAL NEAR BEND, OREG.

Water is diverted from the right bank of Deschutes River about 3 miles above Bend by the Deschutes Irrigation and Power Company. About 2 miles above Bend the ditch divides, forming the Central Oregon canal on the right and the Pilot Butte canal on the left.

The gage on Pilot Butte canal is a vertical rod on the south bank at canal-survey station 88+25, a short distance below the division point and waste weir. The bench mark is a copper bolt cemented in the rock about 2 feet from the gage. Its elevation is 4.76 feet above the datum of the gage. Measurements were made during 1905 by wading. The gage was read during a portion of the year by G. A. Wilson and Z. T. Gideon, employees of the Deschutes Irrigation and Power Company.

*Discharge measurements of Pilot Butte canal near Bend, Oreg., in 1905.*

| Date. | Hydrographer | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| May 17 | Ivan Landes | 31.0 | 22.0 | 1.00 | 1.70 | 22.1 |
| June 22 | do | 32.0 | 40.6 | 1.52 | 2.11 | 61.7 |
| August 10 | do | 32.0 | 47.0 | 1.72 | 2.30 | 80.8 |
| September 22 | do | 31.5 | 38.7 | 1.29 | 2.03 | 49.8 |
| November 16 | do | 30.0 | 28.8 | 1.96 | 2.02 | 56.6 |



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*Daily gage height, in feet, of Pilot Butte canal near Bend, Oreg., for 1905.*

| Day. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.92 | ..... | 1.1 | 0.0 | 1.4 | 2.22 | 2.25 | 2.05 | 1.65 |
| 2 | ..... | 1.78 | ..... | 1.15 | 1.25 | .7 | 2.38 | 2.22 | 2.05 | 1.65 |
| 3 | ..... | 1.78 | ..... | 1.12 | 1.25 | 1.4 | 2.38 | 1.12 | 2.05 | 1.65 |
| 4 | ..... | 1.78 | ..... | 1.15 | 1.25 | 1.4 | 2.4 | 2.25 | 2.05 | 1.8 |
| 5 | ..... | 1.78 | ..... | 1.15 | 1.25 | 1.4 | 2.4 | 2.25 | 2.05 | 1.95 |
| 6 | 1.72 | ..... | ..... | .6 | 1.25 | 1.4 | 2.3 | 2.25 | 2.05 | 1.95 |
| 7 | ..... | ..... | ..... | 1.12 | .0 | 1.4 | 2.2 | 2.25 | 2.05 | 1.95 |
| 8 | 1.72 | ..... | ..... | 1.05 | .0 | 1.4 | 2.35 | 2.25 | 2.05 | 1.8 |
| 9 | 1.73 | ..... | ..... | 1.1 | 1.25 | .0 | 2.2 | 2.25 | 2.05 | 1.95 |
| 10 | 1.73 | ..... | ..... | 1.1 | 1.16 | 1.4 | 2.15 | 2.25 | 2.05 | 1.95 |
| 11 | 1.47 | ..... | ..... | 1.1 | 1.35 | .0 | 2.2 | 2.25 | 2.05 | 1.65 |
| 12 | 1.47 | ..... | ..... | 1.1 | 1.0 | 1.4 | 2.3 | 2.25 | 2.05 | 1.6 |
| 13 | 1.47 | ..... | ..... | 1.1 | .98 | .0 | 2.25 | 2.22 | 2.05 | 1.75 |
| 14 | 1.64 | ..... | ..... | 1.1 | 1.3 | 1.4 | 2.2 | 2.25 | 2.05 | 1.95 |
| 15 | 1.64 | ..... | ..... | .55 | .0 | .35 | 2.18 | 2.25 | 2.05 | 1.6 |
| 16 | 1.76 | ..... | ..... | 1.15 | 1.2 | 1.4 | 2.2 | 2.25 | 2.05 | .8 |
| 17 | 1.76 | ..... | ..... | 1.18 | 1.35 | 1.4 | 2.22 | 2.25 | 2.05 | .0 |
| 18 | 2.0 | ..... | ..... | 1.15 | 1.05 | .0 | 2.25 | 2.18 | 2.05 | 1.85 |
| 19 | 2.0 | ..... | ..... | 1.15 | 1.12 | 1.45 | 2.25 | 2.2 | 2.05 | 1.95 |
| 20 | 1.34 | ..... | ..... | .4 | 1.4 | 1.4 | 2.25 | 2.18 | 2.05 | 1.95 |
| 21 | 1.34 | ..... | ..... | .4 | 1.4 | 1.4 | 2.2 | 2.18 | 2.05 | 1.95 |
| 22 | 1.72 | ..... | ..... | 1.25 | 0.0 | 1.38 | 2.2 | 2.12 | 2.0 | .95 |
| 23 | 1.81 | ..... | ..... | 1.25 | 1.4 | 1.38 | 2.22 | 2.1 | 2.0 | .0 |
| 24 | 1.8 | ..... | ..... | 1.25 | 1.4 | 1.4 | 2.25 | 2.1 | 2.0 | .0 |
| 25 | 1.8 | ..... | ..... | 1.25 | 1.4 | 1.35 | 2.24 | 2.1 | 1.87 | .0 |
| 26 | 1.8 | ..... | ..... | 1.25 | .8 | 1.4 | 2.22 | 2.1 | 1.82 | 1.92 |
| 27 | 1.8 | ..... | ..... | 1.25 | 1.5 | 1.38 | 2.22 | 2.1 | 2.0 | 1.95 |
| 28 | 1.92 | ..... | ..... | 1.12 | 1.35 | 1.4 | 2.3 | 2.1 | 2.0 | .95 |
| 29 | 1.92 | ..... | ..... | 1.25 | .0 | ..... | 2.25 | 2.1 | 2.0 | .0 |
| 30 | 1.92 | ..... | ..... | 1.25 | 1.4 | ..... | 2.28 | 2.05 | 2.0 | .0 |
| 31 | 1.92 | ..... | ..... | ..... | 1.4 | ..... | ..... | 2.05 | ..... | .0 |

NOTE.—Gage readings June 1 to August 28 on weir above waste gate. Length of weir 15 feet with end contractions.

*Station rating table for Pilot Butte canal near Bend, Oreg., from March 6 to December 31, 1905.*

| Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* | *Feet.* | *Second-feet.* |
| 1.00 | 2 | 1.40 | 10 | 1.80 | 30 | 2.20 | 70 |
| 1.10 | 3 | 1.50 | 14 | 1.90 | 39 | 2.30 | 81 |
| 1.20 | 5 | 1.60 | 18 | 2.00 | 49 | 2.40 | 93 |
| 1.30 | 7 | 1.70 | 23 | 2.10 | 59 | | |

The above table is applicable only for open-channel conditions. It is based on five discharge measurements made during 1905. It is well defined between gage heights 1.7 feet and 2.4 feet.

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*Estimated monthly discharge of Pilot Butte canal near Bend, Oreg., for 1905.*

| Month. | Discharge in second-feet. | | | Total in acre-feet. |
|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | |
| March (26 days) | 40 | 8 | 27.2 | 1,403 |
| April (5 days) | 41 | 29 | 31.4 | 311 |
| June | 68.6 | 12.6 | 55.7 | 3,314 |
| July | 89.9 | .0 | 56.3 | 3,462 |
| August | 85.7 | .0 | 66.8 | 4,107 |
| September | 93 | 65 | 76.3 | 4,540 |
| October | 76 | 3 | 66.8 | 4,107 |
| November | 54 | 32 | 51.3 | 3,053 |
| December | 44 | .0 | 23.2 | 1,426 |
| The period | | | | 25,720 |

NOTE.—Discharge approximated March 7 and August 29–31.

### COLUMBIA SOUTHERN CANAL NEAR BEND, OREG.

This canal diverts water from the left bank of Tumallo Creek directly west of Bend, Oreg.

*Discharge measurements of Columbia Southern canal near Bend, Oreg., in 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| | | *Second-feet.* |
| June 21 | Ivan Landes | 48.3 |
| August 10 | ....do | 69.4 |

### CARMICHAEL DITCH AT PRINEVILLE, OREG.

This ditch diverts water from Crooked River at Prineville, Oreg.

*Discharge measurements of Carmichael ditch at Prineville, Oreg., in 1905.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| | | *Second-feet.* |
| May 18 | Ivan Landes | 34.7 |
| June 19 | ....do | 15.7 |
| August 11 | ....do | 7.1 |

## HOOD RIVER DRAINAGE BASIN.

Hood River rises on the northern slopes of Mount Hood and flows northwestward, entering Columbia River at Hood River, Oreg.

### HOOD RIVER AT WINANS CITY, OREG.

This station was established November 17, 1905, by L. R. Allen. It is located 300 feet below the junction of the main forks of the river, at Winans City, 10½ miles above Hood River post-office, Oreg.

The channel is straight for 300 feet above and below the station. Both banks are high, rocky, slightly wooded, and do not overflow. The bed of the stream is of coarse gravel and is free from vegetation and shifting. There is but one channel at all stages. The stream has much fall at all points, and the current is almost a continuous rapid.

Discharge measurements are made by means of a cable, car, tagged wire, and stay line. The initial point for soundings is a tin tag soldered to the tag wire 2.5 feet from the anchorage on the left bank.

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The gage is a staff in two sections. The lower section is inclined and securely fastened to the rock and tree above. The upper section is vertical, and is fastened to an alder tree. The total height of the gage is 20 feet. It is read once each day by W. R. Winans. The bench mark is the highest point on large rock about 15 feet south of the inclined portion of the gage; elevation, 18.20 feet above the datum of the gage.

*Discharge measurements of Hood River at Winans City, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| November 17 | L. R. Allen | 90 | 147 | 3.36 | 0.57 | 493 |
| December 23 | do | 90 | 180 | 4.27 | 1.03 | 767 |

*Daily gage height, in feet, of Hood River at Winans City, Oreg., for 1905.*

| Day. | Nov. | Dec. | Day. | Nov. | Dec. | Day. | Nov. | Dec. | Day. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0.7 | 9 | | 1.0 | 17 | | 1.8 | 25 | 0.7 | 0.7 |
| 2 | | .7 | 10 | | 1.0 | 18 | | 1.6 | 26 | 1.3 | 1.7 |
| 3 | | .7 | 11 | | 1.0 | 19 | 1.5 | 1.6 | 27 | 1.0 | 1.6 |
| 4 | | .7 | 12 | | .9 | 20 | 1.0 | 1.4 | 28 | .9 | 1.5 |
| 5 | | .8 | 13 | | .8 | 21 | .8 | 1.2 | 29 | .8 | 1.3 |
| 6 | | .8 | 14 | | .7 | 22 | .8 | 1.2 | 30 | .7 | 1.0 |
| 7 | | .9 | 15 | | .7 | 23 | .8 | 1.0 | 31 | | .9 |
| 8 | | .9 | 16 | | .7 | 24 | .7 | .8 | | | |

## WILLAMETTE RIVER DRAINAGE BASIN.

### DESCRIPTION OF BASIN.

Willamette River is formed by the junction of Coast Fork and Middle Fork near Eugene, Oreg. Coast Fork rises on the eastern slope of the Coast Range and Middle Fork rises on the western slope of the Cascade Mountains. A short distance below the junction the Willamette receives the waters of McKenzie Fork, a large stream from the east. Other tributaries of note are Santiam, Luckiamute, Molalla, and Clackamas rivers.

### MIDDLE FORK OF WILLAMETTE RIVER AT JASPER, OREG.

This station was established September 16, 1905, by L. R. Allen. It is located at Jasper Ferry, Jasper post-office, Oreg., 2 miles above Natron, and 3 miles below the mouth of Fall Creek.

The channel is straight for 800 feet above and 700 feet below the station. The current is swift. The right bank is high, covered with brush, and not liable to overflow. The left bank is lower, clear of brush, and is liable to overflow during extreme floods. The bed of the stream is composed of gravel or small bowlders and is free from vegetation and shifting. There is but one channel at all stages. The accuracy of measurements may be affected by floating logs.

Discharge measurements are made by means of a cable, car, tagged wire, and stay line. The initial point for soundings is a tin tag on the tagged wire 17 feet from the cable support on the right bank.

The gage is a vertical staff 18 feet long spiked to a tree on the right bank, 30 feet above the cable. During 1905 the gage was read once each day by W. H. Eaton. The bench mark is the top of three 30-penny nails driven into the left sill near the first vertical rod of a bridge across a small creek, 400 feet below the cable; elevation, 21.43 feet above the datum of the gage.

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*Discharge measurements of Middle Fork of Willamette River at Jasper, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| September 16 | L. R. Allen | 322 | 652 | 1.16 | 1.25 | 758 |
| December 29 | do | 354 | 1,366 | 2.88 | 3.27 | 3,925 |

*Daily gage height, in feet, of Middle Fork of Willamette River at Jasper, Oreg., for 1905.*

| Day. | Sept. | Oct. | Nov. | Dec. | Day. | Sept. | Oct. | Nov. | Dec. | Day. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 1.5 | 1.7 | 3.2 | 12 | | 1.7 | 1.5 | 2.5 | 23 | 1.2 | 1.8 | 2.0 | 2.5 |
| 2 | | 1.5 | 1.7 | 3.2 | 13 | | 1.7 | 1.5 | 2.4 | 24 | 1.2 | 1.7 | 1.9 | 2.4 |
| 3 | | 1.4 | 1.7 | 3.4 | 14 | | 1.7 | 1.4 | 2.3 | 25 | 1.2 | 1.9 | 1.8 | 2.3 |
| 4 | | 1.4 | 1.7 | 3.6 | 15 | | 1.6 | 1.4 | 2.3 | 26 | 1.3 | 2.8 | 1.8 | 3.6 |
| 5 | | 1.4 | 1.7 | 3.2 | 16 | | 2.5 | 1.4 | 2.2 | 27 | 1.5 | 2.4 | 2.8 | 4.1 |
| 6 | | 1.9 | 1.7 | 3.1 | 17 | 1.3 | 2.1 | 1.4 | 2.3 | 28 | 1.9 | 2.2 | 2.5 | 3.9 |
| 7 | | 3.1 | 1.6 | 3.2 | 18 | 1.3 | 2.6 | 1.7 | 2.4 | 29 | 1.7 | 1.9 | 2.4 | 3.4 |
| 8 | | 2.8 | 1.6 | 3.5 | 19 | 1.3 | 2.5 | 1.9 | 2.5 | 30 | 1.6 | 1.9 | 3.1 | 3.5 |
| 9 | | 2.2 | 1.6 | 3.1 | 20 | 1.3 | 2.1 | 3.0 | 2.9 | 31 | | 1.8 | | 4.1 |
| 10 | | 1.9 | 1.5 | 2.9 | 21 | 1.3 | 2.0 | 2.3 | 2.8 | | | | | |
| 11 | | 1.8 | 1.5 | 2.6 | 22 | 1.2 | 1.9 | 2.1 | 2.6 | | | | | |

## COAST FORK OF WILLAMETTE RIVER NEAR GOSHEN, OREG.

This station was established August 23, 1905, by L. R. Allen. It is located at the highway bridge 3 miles east of Goshen, Oreg., 9 miles southeast of Eugene, and about 4 miles above the junction of Coast and Middle forks of Willamette River.

The channel is straight for 500 feet above and 800 feet below the station. The water flows with an even current. Both banks are covered with undergrowth and liable to overflow during flood stages. The bed of the stream is of coarse gravel or small bowlders, is free from vegetation, and is liable to shift during high water. There is but one channel at all stages, broken by the piers of the bridge.

Discharge measurements are made from the downstream side of the highway bridge, 530 feet in length, including approaches. The initial point for soundings is two 6-penny nails driven into the first plank of the left approach of the bridge, downstream side. Low-water measurements are made by wading about 100 feet below the bridge.

The gage is in two sections. The lower section is a vertical staff fastened to an old pier in the center of the stream; the upper section is a vertical scale painted on the lower bridge caisson on the left bank. The total length of the gage is 18 feet. During 1905 the gage was read once each day by John D. West. The bench mark is the top of a large circular washer over the center of the bridge caisson on which the upper portion of the gage is painted; elevation, 26.25 feet above the datum of the gage.

*Discharge measurements of Coast Fork of Willamette River near Goshen, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 23 | L. R. Allen | 80 | 47 | 1.42 | 0.30 | 68 |
| November 7 | do | 165 | 204 | .89 | .67 | 182 |
| December 29 | do | 241 | 677 | 2.82 | 2.78 | 1,908 |

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*Daily gage height, in feet, of Coast Fork of Willamette River near Goshen, Oreg., for 1906*

| Day. | Aug. | Sept. | Oct. | Nov. | Dec. | Day. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 0.25 | ..... | 1.0 | 2.9 | 17 | ..... | 0.25 | 1.5 | 0.4 | 1.5 |
| 2 | ..... | .25 | ..... | .9 | 3.0 | 18 | ..... | .25 | 1.3 | .6 | 1.5 |
| 3 | ..... | .25 | ..... | .8 | 3.1 | 19 | ..... | .25 | 1.3 | 1.0 | 1.9 |
| 4 | ..... | .25 | 0.5 | .6 | 3.3 | 20 | ..... | .25 | 1.1 | 2.3 | 3.1 |
| 5 | ..... | .25 | .5 | .6 | 2.8 | 21 | ..... | ..... | 1.0 | 1.9 | 3.0 |
| 6 | ..... | .25 | .5 | .5 | 2.5 | 22 | ..... | ..... | 1.0 | 1.5 | 2.5 |
| 7 | ..... | .25 | 1.4 | .5 | 2.7 | 23 | ..... | 0.3 | ..... | .9 | 1.3 | 2.0 |
| 8 | ..... | .2 | 2.3 | .5 | 3.2 | 24 | ..... | .3 | ..... | .8 | 1.3 | 1.9 |
| 9 | ..... | .2 | 1.5 | .4 | 2.6 | 25 | ..... | .3 | ..... | .9 | 1.2 | 1.7 |
| 10 | ..... | .2 | 1.01 | .4 | 2.2 | 26 | ..... | .3 | ..... | 2.0 | 1.0 | 2.2 |
| 11 | ..... | .2 | 1.0 | .4 | 2.0 | 27 | ..... | .3 | ..... | 1.7 | 2.2 | 2.7 |
| 12 | ..... | .2 | .8 | .4 | 2.0 | 28 | ..... | .3 | ..... | 1.5 | 2.3 | 2.3 |
| 13 | ..... | .25 | .7 | .4 | 1.9 | 29 | ..... | .25 | ... ... | 1.3 | 1.9 | 2.8 |
| 14 | ..... | .25 | .6 | .3 | 1.5 | 30 | ..... | .25 | ..... | 1.2 | 3.0 | 3.0 |
| 15 | ..... | .25 | .7 | .3 | 1.3 | 31 | ..... | .25 | ..... | 1.0 | ..... | 5.0 |
| 16 | ..... | .25 | 1.9 | .3 | 1.5 | | | | | | |

## M'KENZIE RIVER AT HENDRICKS FERRY, OREG.

This station was established September 12, 1905, by L. R. Allen. It is located at Hendricks Ferry, 11 miles above Springfield, about 3 miles above the mouth of Camp Creek.

The channel is straight for 500 feet above and 800 feet below the station. The current is swift. The right bank is comparatively high, clean, and liable to overflow during extreme floods. The left bank is somewhat higher, covered with brush, and does not overflow. The bed of the stream is composed of coarse gravel or small bowlders and is free from vegetation and shifting. There is but one channel at all stages. The accuracy of measurements may be affected by floating logs during the running season.

Discharge measurements are made by means of a cable, car, tagged wire, and stay line. The initial point for soundings is a tin tag on the tagged wire 6 feet from the cable support on the left bank.

The gage is a vertical staff spiked to a willow tree about 250 feet above the cable, on the left bank. During 1905 the gage was read once each day by Grant Hendricks. The bench mark is the top of a three-fourths-inch bolt cemented in the rock about 30 feet below the gage rod, on the left bank; elevation, 14.22 feet above the datum of the gage and 571.61 feet above sea level, the latter elevation being obtained from a bench mark set by a professor and students of the University of Oregon.

*Discharge measurements of McKenzie River at Hendricks Ferry, Oreg., in 1906.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| September 12 | L. R. Allen | 395 | 928 | 1.69 | 1.30 | 1,571 |
| November 10 | do | 398 | 880 | 2.05 | 1.12 | 1,805 |
| December 30 | do | 404 | 1,369 | 3.58 | 2.65 | 4,907 |

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*Daily gage height, in feet, of McKenzie River at Hendricks Ferry, Oreg., for 1905.*

| Day. | Sept. | Oct. | Nov. | Dec. | Day. | Sept. | Oct. | Nov. | Dec. | Day. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1..... | ..... | 1.5 | 1.3 | 2.0 | 12..... | 1.3 | 1.45 | 1.1 | 1.9 | 22 ..... | 1.3 | 1.4 | 1.55 | 1.95 |
| 2..... | ..... | 1.5 | 1.3 | 2.2 | 13..... | 1.35 | 1.5 | 1.1 | 1.85 | 23..... | 1.3 | 1.3 | 1.4 | 1.8 |
| 3..... | ..... | 1.45 | 1.25 | 2.4 | 14..... | 1.3 | 1.7 | 1.1 | 1.8 | 24..... | 1.3 | 1.3 | 1.35 | 1.85 |
| 4..... | ..... | 1.5 | 1.25 | 2.45 | 15..... | 1.3 | 2.3 | 1.1 | 1.75 | 25..... | 1.7. | 1.85 | 1.25 | 1.7 |
| 5..... | ..... | 1.55 | 1.2 | 2.2 | 16..... | 1.3 | 1.9 | 1.1 | 1.75 | 26..... | 1.55 | 2.1 | 1.8 | 3.4 |
| 6..... | ..... | 1.75 | 1.2 | 2.2 | 17..... | 1.3 | 1.5 | 1.1 | 2.35 | 27..... | 1.5 | 1.75 | 1.8 | 3.1 |
| 7..... | ..... | 2.8 | 1.2 | 2.9 | 18..... | 1.3 | 1.9 | 1.3 | 2.2 | 28..... | 1.5 | 1.6 | 1.75 | 2.6 |
| 8..... | ..... | 2.3 | 1.2 | 2.9 | 19..... | 1.3 | 1.6 | 1.8 | 2.1 | 29..... | 1.5 | 1.5 | 1.9 | 2.24 |
| 9..... | ..... | 1.8 | 1.1 | 2.4 | 20..... | 1.3 | 1.5 | 1.75 | 2.2 | 30..... | 1.5 | 1.4 | 2.3 | 2.8 |
| 10..... | ..... | 1.7 | 1.1 | 2.2 | 21..... | 1.3 | 1.4 | 1.6 | 1.9 | 31..... | ..... | 1.35 | ..... | 2.7 |
| 11..... | ..... | 1.4 | 1.1 | 2.0 | | | | | | | | | | |

## WILLAMETTE RIVER AT ALBANY, OREG.

This station was established July 21, 1905, by L. R. Allen. It is located at the Corvallis and Eastern Railroad bridge at Albany, Oreg., just above the mouth of Calipooia Creek and 7 miles above the mouth of Santiam River.

The channel is slightly curved for about half a mile above and straight for half a mile below the station. The current is uniform and has a medium velocity. The right bank is high, composed of sand and fine gravel, covered with brush, and does not overflow. The left bank is low, composed of sand and gravel, covered with brush, and subject to overflow during high water. The bed of the stream is of sand and fine gravel, is free from vegetation, and is liable to shift during high water. There is one channel at low and two at high stages, broken by the piers of the bridge.

Discharge measurements are made from the upstream side of the railway bridge. The initial point for soundings is a large nail driven into the upstream guard rail over the center of the right-bank pier.

The gage is a vertical staff fastened to the lower end of the right-bank bridge pier. The gage reads to 36 feet. During 1905 the gage was read once each day by Fred Aldrich. The bench mark is the top of a railroad spike driven into a cross sill over the second pier from the right bank, downstream side; elevation, 48.05 feet above the datum of the gage.

July 20, 1905, a discharge measurement made at this station by L. R. Allen gave the following results: Area of section, 3,724 square feet; mean velocity, 0.92 foot per second; gage height, 3.29 feet; discharge, 3,433 second-feet.

*Daily gage height, in feet, of Willamette River at Albany, Oreg., for 1905.*

| Day. | Sept. | Oct. | Nov. | Dec. | Day. | Sept. | Oct. | Nov. | Dec. | Day. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1..... | 2.3 | 2.8 | 3.4 | 5.35 | 12..... | 2.2 | 3.5 | 2.7 | 5.05 | 22 ..... | 2.2 | 3.5 | 4.25 | 6.65 |
| 2..... | 2.3 | 2.8 | 3.2 | 5.6 | 13..... | 2.2 | 3.2 | 2.7 | 4.1 | 23..... | 2.2 | 3.5 | 3.1 | 5.75 |
| 3..... | 2.3 | 2.8 | 3.1 | 6.25 | 14..... | 2.2 | 3.2 | 2.6 | 4.75 | 24..... | 2.2 | 3.3 | 3.6 | 5.7 |
| 4..... | 2.3 | 2.8 | 3.05 | 6.5 | 15..... | 2.2 | 2.11 | 2.7 | 4.7 | 25..... | 2.2 | 3.2 | 3.5 | 5.1 |
| 5..... | 2.05 | 2.8 | 3.1 | 6.55 | 16..... | 2.2 | 2.11 | 2.6 | 4.45 | 26..... | 2.2 | 3.2 | 3.45 | 5.5 |
| 6..... | 2.05 | 2.95 | 3.1 | 5.6 | 17..... | 2.2 | 3.1 | 2.6 | 4.45 | 27..... | 2.3 | 4.3 | 3.4 | 7.6 |
| 7..... | 2.2 | 2.11 | 2.11 | 5.5 | 18..... | 2.2 | 3.1 | 2.6 | 4.8 | 28..... | 2.4 | 4.1 | 4.55 | 7.6 |
| 8..... | 2.2 | 3.11 | 2.11 | 6.2 | 19..... | 2.2 | 4.05 | 2.6 | 4.9 | 29..... | 2.7 | 3.11 | 4.5 | 7.8 |
| 9..... | 2.2 | 4.9 | 2.10 | 6.85 | 20..... | 2.2 | 3.11 | 3.65 | 5.75 | 30..... | 2.7 | 3.7 | 4.55 | 7.45 |
| 10..... | 2.2 | 4.2 | 2.10 | 5.6 | 21..... | 2.2 | 3.7 | 4.45 | 6.75 | 31..... | ..... | 3.5 | ..... | 8.8 |
| 11..... | 2.2 | 3.7 | 2.7 | 5.6 | | | | | | | | | | |

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### SANTIAM RIVER AT JEFFERSON, OREG.

This station was established July 19, 1905, by L. R. Allen. It is located at the Southern Pacific Railroad bridge at Jefferson, Oreg., 2½ miles below the junction of North and South forks.

The channel is straight for 500 feet above and 700 feet below the station. The current is uniform and sluggish at low water. The right bank is comparatively high, clean at the station, and liable to overflow but little during extreme high water. The left bank is low, clean, and liable to overflow. The bed of the stream is composed of rock and coarse gravel, is free from vegetation, and is liable to shift during floods. There is but one channel at low water, broken by the piers of the bridge, but during floods water runs over the left bank and through a slough several hundred feet to the right of the main channel. The accuracy of measurements may be affected by rafts of logs at the mill near by during low water.

Discharge measurements are made from the upstream side of the Southern Pacific Railroad bridge. The initial point for soundings is on the upstream guard rail, near the end of the rail on the right-bank trestle.

The gage is a vertical staff fastened to the lower side of the bridge piers. During 1905 the gage was read once each day by C. Alsted. The bench mark is the top of four 30-penny nails driven into the cross sill over the center of the right-bank pier; elevation, 35.22 feet above the datum of the gage.

July 18, 1905, a discharge measurement made at this station by L. R. Allen gave the following results: Width, 326 feet; area of section, 2,659 square feet; mean velocity, 0.31 foot per second; gage height, 3.41 feet; discharge, 817 second-feet.

*Daily gage height, in feet, of Santiam River at Jefferson, Oreg., for 1905.*

| Day. | Oct. | Nov. | Dec. | Day. | Oct. | Nov. | Dec. | Day. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 4.5 | 6.15 | 12 | 5.0 | 3.8 | 5.8 | 22 | 4.65 | 5.0 | 6.0 |
| 2 | ..... | 4.4 | 6.85 | 13 | 4.8 | 3.7 | 5.5 | 23 | 4.5 | 4.7 | 5.8 |
| 3 | ..... | 4.3 | 6.95 | 14 | 4.6 | 3.7 | 5.4 | 24 | 4.5 | 4.5 | 5.5 |
| 4 | ..... | 4.2 | 6.9 | 15 | 4.8 | 3.6 | 5.2 | 25 | 4.8 | 4.4 | 5.4 |
| 5 | ..... | 4.15 | 6.5 | 16 | 5.9 | 3.6 | 5.2 | 26 | 6.5 | 4.5 | 7.6 |
| 6 | ..... | 4.1 | 6.5 | 17 | 5.4 | 3.6 | 6.2 | 27 | 5.8 | 5.6 | 7.4 |
| 7 | ..... | 4.0 | 6.9 | 18 | 5.7 | 3.9 | 6.6 | 28 | 5.4 | 5.3 | 6.8 |
| 8 | 7.5 | 4.0 | 7.4 | 19 | 5.4 | 4.5 | 6.5 | 29 | 5.0 | 5.3 | 6.5 |
| 9 | 6.6 | 3.9 | 6.8 | 20 | 5.0 | 6.1 | 6.8 | 30 | 4.8 | 6.0 | 6.8 |
| 10 | 5.95 | 3.9 | 6.2 | 21 | 4.8 | 5.35 | 6.5 | 31 | 4.6 | ..... | 6.95 |
| 11 | 5.4 | 3.8 | 6.0 | | | | | | | | |

### NORTH FORK OF SANTIAM RIVER NEAR MEHAMA, OREG.

This station was established July 11, 1905, by L. R. Allen. It is located just below the highway bridge at Mehama, Oreg., about 1½ miles north of Lyons, the nearest railroad station. The station is about 12 miles below the junction of Little North Fork and North Fork.

The channel is straight for about 600 feet above and 300 feet below the station. The current is swift and regular. The right bank is high, rocky, timbered, and does not overflow. The left bank is low, covered with some brush, and is subject to overflow during floods. The bed of the stream is of rock or coarse gravel, free from vegetation, and liable to shift slightly during floods.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is zero of the tagged wire, 25 feet from the cable support on the right bank.

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The gage is a staff in two sections. The lower section is inclined. The upper section is vertical, being fastened at the lower end to the inclined section. During 1905 the gage was read once each day by F. U. Hull. The bench mark is the top of a 1-inch bolt cemented in soft sandstone near the gage rod; elevation, 12.60 feet above the datum of the gage.

*Discharge measurements of North Fork of Santiam River near Mehama, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| July 11 | L. R. Allen | 160 | 756 | 1.38 | 2.90 | 1,048 |
| October 18 | do | 202 | 1,013 | 3.51 | 4.44 | 3,556 |
| November 16 | J. H. Lewis | 155 | 756 | 1.29 | 2.90 | 973 |
| December 12 | L. R. Allen | 250 | 927 | 3.11 | 4.24 | 2,881 |

*Daily gage height, in feet, of North Fork of Santiam River near Mehama, Oreg., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2.65 | 2.5 | 3.35 | 3.55 | 4.3 | 17 | 2.8 | 2.6 | 2.6 | 4.4 | 2.9 | 5.75 |
| 2 | | 2.65 | 2.5 | 3.55 | 3.4 | 5.0 | 18 | 2.8 | 2.6 | 2.55 | 4.45 | 3.35 | 5.4 |
| 3 | | 2.65 | 2.5 | 3.4 | 3.4 | 5.3 | 19 | 2.75 | 2.6 | 2.55 | 4.15 | 4.8 | 5.4 |
| 4 | | 2.65 | 2.5 | 6.8 | 3.4 | 5.1 | 20 | 2.75 | 2.55 | 2.55 | 3.95 | 4.6 | 5.05 |
| 5 | | 2.65 | 2.5 | 5.1 | 3.4 | 5.0 | 21 | 2.75 | 2.55 | 2.55 | 3.8 | 4.0 | 4.75 |
| 6 | | 2.65 | 2.5 | 5.35 | 3.25 | 5.1 | 22 | 2.75 | 2.55 | 2.55 | 3.7 | 3.8 | 4.45 |
| 7 | | 2.65 | 2.5 | 6.6 | 3.2 | 5.5 | 23 | 2.75 | 2.55 | 2.5 | 3.6 | 3.7 | 4.3 |
| 8 | | 2.65 | 2.45 | 5.9 | 3.15 | 5.6 | 24 | 2.7 | 2.55 | 2.5 | 3.65 | 3.55 | 4.1 |
| 9 | | 2.6 | 2.45 | 5.2 | 3.1 | 5.0 | 25 | 2.7 | 2.5 | 4.35 | 5.1 | 3.5 | 4.0 |
| 10 | | 2.6 | 2.45 | 4.7 | 3.1 | 4.7 | 26 | 2.7 | 2.5 | 4.35 | 5.2 | 4.4 | 5.9 |
| 11 | | 2.6 | 2.45 | 4.3 | 3.1 | 4.4 | 27 | 2.7 | 2.5 | 3.25 | 4.6 | 4.2 | 5.25 |
| 12 | 2.9 | 2.6 | 2.55 | 4.1 | 3.0 | 4.3 | 28 | 2.7 | 2.55 | 3.35 | 4.25 | 4.0 | 4.9 |
| 13 | 2.9 | 2.6 | 2.8 | 3.9 | 3.0 | 4.15 | 29 | 2.7 | 2.55 | 3.35 | 4.0 | 4.1 | 4.55 |
| 14 | 2.8 | 2.6 | 2.7 | 3.7 | 2.95 | 4.1 | 30 | 2.65 | 2.55 | 3.5 | 3.85 | 4.55 | 4.7 |
| 15 | 2.8 | 2.6 | 2.55 | 4.9 | 2.9 | 4.1 | 31 | 2.65 | 2.5 | ..... | 3.65 | ..... | 4.6 |
| 16 | 2.8 | 2.5 | 2.5 | 4.6 | 2.9 | 4.1 | | | | | | | |

## SOUTH FORK OF SANTIAM RIVER AT WATERLOO, OREG.

This station was established July 28, 1905, by L. R. Allen. It is located about one-half mile below the highway bridge at Waterloo, Oreg. The station is about 4 miles above the mouth of Hamilton Creek, and about 3 miles above a dam which diverts water into a canal for the use of the town of Albany.

The channel is straight for 800 feet above and below the station. The current has a good uniform velocity. Both banks are fairly high and thickly covered with undergrowth, but are liable to overflow during extreme floods. The bed of the stream is of coarse gravel or small bowlders, is free from vegetation, and is liable to shift during floods. There is but one channel at all stages.

Discharge measurements are made by means of a cable, car, tagged wire, and stay line. The initial point for soundings is a tin tag on the tagged wire, 2½ feet from the cable support at the right bank.

The gage is on the right bank about 100 feet below the cable. It is a staff in two sections, the lower inclined, the upper vertical. During 1905 the gage was read once each day by John B. Hudelson. Bench marks were established as follows: (1) The top of a three-fourths-inch bolt cemented in rock near the lower portion of the gage rod; elevation, 2.88

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feet. (2) The top of five 30-penny nails driven into the root of a large fir tree about 300 feet below the cable on the right bank; elevation, 24.70 feet. Elevations refer to the datum of the gage.

July 28, 1905, a discharge measurement made at this station by L. R. Allen gave the following results: Width, 150 feet; area of section, 246 square feet; mean velocity, 1.52 feet per second; gage height, 1.06 feet; discharge, 375 second-feet.

*Daily gage height, in feet, of South Fork of Santiam River at Waterloo, Oreg., for 1905.*

| Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Day. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 1.05 | 0.8 | 1.9 | 2.1 | 3.4 | 17 | ..... | 1.0 | .9 | 2.9 | 1.4 | 4.0 |
| 2 | ..... | 1.0 | .8 | 1.5 | 2.0 | 3.9 | 18 | ..... | 1.0 | .9 | 3.3 | 1.8 | 3.7 |
| 3 | ..... | 1.0 | .8 | 1.6 | 2.2 | 4.2 | 19 | ..... | 1.0 | .9 | 2.4 | 2.0 | 3.8 |
| 4 | ..... | 1.0 | .7 | 4.5 | 1.9 | 4.2 | 20 | ..... | 1.0 | .9 | 2.5 | 3.2 | 4.0 |
| 5 | ..... | 1.0 | .7 | 3.0 | 1.9 | 3.2 | 21 | ..... | 1.0 | .8 | 2.3 | 2.2 | 3.6 |
| 6 | ..... | 1.0 | .7 | 3.1 | 1.9 | 3.9 | 22 | ..... | .9 | .8 | 2.2 | 2.3 | 3.3 |
| 7 | ..... | 1.0 | .7 | 3.5 | 1.7 | 4.5 | 23 | ..... | .9 | .8 | 2.2 | 2.1 | 3.1 |
| 8 | ..... | 1.0 | .6 | 4.4 | 1.6 | 4.9 | 24 | ..... | .9 | .8 | 2.0 | 2.0 | 2.7 |
| 9 | ..... | 1.0 | .6 | 3.6 | 1.6 | 4.9 | 25 | ..... | .9 | .8 | 2.3 | 1.9 | 2.7 |
| 10 | ..... | 1.0 | .6 | 3.0 | 1.5 | 4.5 | 26 | ..... | .8 | 1.0 | 3.9 | 2.0 | 3.5 |
| 11 | ..... | 1.0 | .6 | 2.6 | 1.5 | 3.2 | 27 | ..... | .8 | 1.9 | 2.8 | 3.1 | 4.4 |
| 12 | ..... | 1.0 | .7 | 2.3 | 1.5 | 3.0 | 28 | ..... | .8 | 1.8 | 2.3 | 2.8 | 4.2 |
| 13 | ..... | 1.0 | .7 | 2.2 | 1.4 | 3.0 | 29 | ..... | 1.05 | .8 | 1.8 | 2.5 | 2.6 | 3.7 |
| 14 | ..... | 1.0 | .9 | 2.0 | 1.4 | 2.7 | 30 | ..... | 1.05 | .8 | 1.5 | 2.3 | 3.4 | 4.0 |
| 15 | ..... | 1.0 | .8 | 2.4 | 1.4 | 2.7 | 31 | ..... | 1.05 | .8 | ..... | 2.3 | ..... | 4.2 |
| 16 | ..... | 1.0 | .8 | 3.9 | 1.4 | 2.7 | | | | | | | | |

## LUCKIAMUTE RIVER NEAR SUVER, OREG.

This station was established August 18, 1905, by L. R. Allen. It is located just below Helmick bridge on the public highway, 4 miles northwest of Suver, Oreg., 2 miles west of Parkers Station, and about 3 miles below the junction of the main forks of the river.

The channel is straight for 300 feet above and below the station. The current is regular.

Both banks are high, covered with brush, and liable to overflow during extreme floods. The bed of the stream is of sand, is free from vegetation, and shifts during floods. There is but one channel at all stages.

Discharge measurements are made by means of a cable, car, tagged wire, and stay line. The initial point for soundings is a tag on the tagged line 7.2 feet from the cable support on the right bank.

The gage is on the left bank at the bridge. It is in two sections, the lower inclined, the upper vertical, both being secured to posts supporting the bridge. The gage rod reads to 32.8 feet. During 1905 the gage was read once each day by Maggie J. Evans. The bench mark is the top of three 30-penny nails driven into the cross sill of the bridge, downstream side, 5 feet from the end of the first panel from the left bank; elevation, 39.86 feet above the datum of the gage.

*Discharge measurements of Luckiamute River near Suver, Oreg., in 1905.*

| Date. | Hydrographer. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Square feet.* | *Feet per second.* | *Feet.* | *Second-feet.* |
| August 18 | L. R. Allen | 45 | 121 | 0.60 | 1.47 | 73 |
| October 7 | do | 79 | 571 | 2.07 | 8.57 | 1,182 |

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*Daily gage height, in feet, of Luckiamute River near Suver, Oreg., for 1905.*

| Day. | Aug. | Sept. | Oct. | Nov. | Dec. | Day. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ..... | 0.95 | 2.5 | 2.8 | 6.6 | 17 | ..... | 1.3 | 3.5 | 2.0 | 8.4 |
| 2 | ..... | .9 | 2.2 | 2.55 | 7.3 | 18 | ..... | 1.1 | 3.5 | 2.1 | 12.0 |
| 3 | ..... | .95 | 2.5 | 2.75 | 7.55 | 19 | ..... | 1.25 | 3.4 | 3.0 | 10.7 |
| 4 | ..... | 1.2 | 9.0 | 2.45 | 7.15 | 20 | 1.25 | 1.5 | 3.3 | 7.75 | 14.35 |
| 5 | ..... | 1.0 | 6.2 | 2.6 | 6.45 | 21 | 1.2 | 1.2 | 3.0 | 5.5 | 13.15 |
| 6 | ..... | 1.5 | 7.1 | 2.4 | 7.25 | 22 | 1.25 | 1.1 | 3.0 | 4.5 | 11.4 |
| 7 | ..... | 1.5 | 7.5 | 2.2 | 7.30 | 23 | 1.5 | 1.1 | 2.85 | 4.15 | 9.75 |
| 8 | ..... | .95 | 7.7 | 2.3 | 7.0 | 24 | 1.1 | 1.1 | 2.8 | 3.75 | 9.2 |
| 9 | ..... | .95 | 6.65 | 2.05 | 6.25 | 25 | .95 | 1.15 | 2.95 | 3.5 | 8.3 |
| 10 | ..... | 1.0 | 6.35 | 2.15 | 6.0 | 26 | 1.0 | 1.8 | 3.65 | 3.2 | 15.4 |
| 11 | ..... | 1.0 | 4.55 | 2.15 | 5.8 | 27 | .95 | 3.2 | 3.1 | 3.7 | 15.2 |
| 12 | ..... | 1.0 | 4.5 | 2.1 | 5.1 | 28 | 1.5 | 3.5 | 3.35 | 3.5 | 13.0 |
| 13 | ..... | 1.1 | 3.6 | 2.0 | 5.1 | 29 | 1.1 | 2.75 | 2.8 | 3.6 | 12.2 |
| 14 | ..... | 1.1 | 3.3 | 2.05 | 4.8 | 30 | 1.4 | 2.6 | 2.8 | 5.55 | 12.4 |
| 15 | ..... | 1.5 | 3.3 | 2.0 | 4.35 | 31 | 1.0 | ..... | 2.7 | ..... | 18.65 |
| 16 | ..... | 1.0 | 4.15 | 2.0 | 4.2 | | | | | | |

## MOLALLA RIVER AT DICKEY PRAIRIE, OREG.

This station was established November 1, 1905, by L. R. Allen. It is located at Dickey Prairie, 3 miles below the junction of the forks of the river, 3½ miles southeast of Molalla, Oreg.

The channel is straight for 400 feet above and below the station. The current is swift and somewhat rough. The right bank is low, wooded, and subject to overflow. The left bank is fairly high, covered with brush, and not liable to overflow. The bed of the stream is of coarse gravel or small bowlders, free from vegetation, and shifting. There is but one channel during low and ordinary stages, but during extreme high water there is a slough on the right bank, which will have to be measured by wading.

Discharge measurements are made by means of a cable, car, tagged line, and stay wire. The initial point for soundings is a tin tag on the tagged wire 7 feet from the cable support on the right bank.

The gage is a staff in two sections on the left bank, about 200 feet above the cable. The lower section is inclined and fastened to the rock. The upper section is vertical and fastened to an alder tree. The total height of the gage is 14.00 feet. It is read once each day by Raymond Dickey. The bench mark is the top of three 30-penny nails driven into a bench made on the root of a fir tree about 20 feet south and 30 feet west of the gage; elevation, 14.85 feet above the datum of the gage.

November 2, 1905, a discharge measurement made at this station by L. R. Allen gave the following results: Width, 106 feet; area of section, 226 square feet; mean velocity, 1.68 feet per second; gage height, 1.83 feet; discharge, 376 second-feet.

*Daily gage height, in feet, of Molalla River at Dickey Prairie, Oreg., for 1905.*

| Day. | Nov. | Dec. | Day. | Nov. | Dec. | Day. | Nov. | Dec. | Day. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.85 | 2.8 | 9 | 1.45 | 3.2 | 17 | 1.25 | 3.8 | 25 | 1.85 | 2.4 |
| 2 | 1.8 | 4.5 | 10 | 1.4 | 2.9 | 18 | 1.6 | 3.5 | 26 | 2.9 | 3.7 |
| 3 | 1.75 | 4.0 | 11 | 1.4 | 2.7 | 19 | 3.7 | 3.4 | 27 | 2.55 | 3.4 |
| 4 | 1.75 | 3.6 | 12 | 1.35 | 2.55 | 20 | 2.9 | 3.2 | 28 | 2.4 | 3.1 |
| 5 | 1.7 | 3.8 | 13 | 1.35 | 2.45 | 21 | 2.5 | 3.1 | 29 | 2.6 | 2.8 |
| 6 | 1.6 | 3.8 | 14 | 1.3 | 2.3 | 22 | 2.25 | 2.85 | 30 | 2.9 | 3.2 |
| 7 | 1.55 | 3.85 | 15 | 1.3 | 2.25 | 23 | 2.05 | 2.7 | 31 | ..... | 3.0 |
| 8 | 1.5 | 3.5 | 16 | 1.25 | 2.45 | 24 | 1.9 | 2.45 | | | |

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### CLACKAMAS RIVER NEAR BARTON, OREG.

This station was established October 2, 1905, by L. R. Allen. It is located 2½ miles below Barton, Oreg., 1½ miles below the mouth of Deep Creek.

The channel is straight for 500 feet above and 600 feet below the station. The current is swift. The right bank is comparatively high, clean, and liable to overflow during extreme floods. The left bank is high, covered with brush, and does not overflow. The bed of the stream is of coarse gravel or small bowlders, free from vegetation, and shifting. There is but one channel at all stages.

Discharge measurements are made by means of a cable, car, tagged wire, and stay wire. The initial point for soundings is the tin tag on the tagged wire 1.7 feet from the cable support on the right bank.

The gage is a staff in two sections, on the right bank at the cable. The lower section is inclined, the upper section is vertical. During 1905 the gage was read once each day by Le Roy Breithaupt. Bench marks were established as follows: (1) The top of three 30-penny nails driven into the sill at the northwest corner of an old barn southeast of the gage; elevation, 19.21 feet. (2) The top of the head of a bolt driven into a large alder tree by the upright portion of the gage; elevation, 16.09 feet. Elevations refer to the datum of the gage.

October 2, 1905, a discharge measurement made at this station by L. R. Allen gave the following results: Width, 310 feet; area of section, 704 square feet; mean velocity, 2.27 feet per second; gage height, 3.30 feet; discharge, 1,598 second-feet.

*Daily gage height, in feet, of Clackamas River near Barton, Oreg., for 1905.*

| Day. | Nov. | Dec. | Day. | Nov. | Dec. | Day. | Nov. | Dec. | Day. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 4.23 | 9 | | 4.8 | 17 | 2.9 | 4.6 | 25 | 3.55 | 4.0 |
| 2 | | 5.47 | 10 | | 4.5 | 18 | 3.1 | 5.3 | 26 | 3.8 | 5.1 |
| 3 | | 5.3 | 11 | | 4.3 | 19 | 3.62 | 5.25 | 27 | 4.33 | 5.05 |
| 4 | | 5.1 | 12 | 3.0 | 4.12 | 20 | 4.7 | 5.2 | 28 | 4.1 | 4.75 |
| 5 | | 4.8 | 13 | 3.0 | 4.0 | 21 | 4.1 | 4.8 | 29 | 4.1 | 4.55 |
| 6 | | 4.8 | 14 | 3.0 | 3.9 | 22 | 3.82 | 4.6 | 30 | 4.19 | 4.5 |
| 7 | | 4.9 | 15 | 3.0 | 3.8 | 23 | 3.7 | 4.33 | 31 | | 4.8 |
| 8 | | 5.13 | 16 | 3.0 | 3.8 | 24 | 3.5 | 4.1 | | | |

## MISCELLANEOUS MEASUREMENTS.

The following miscellaneous discharge measurements were made in the Columbia River drainage basin in Oregon in 1905:

*Miscellaneous discharge measurements made in Columbia River drainage basin in Oregon in 1905.*

| Date. | Stream. | Locality. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | | *Feet.* | *Square feet.* | *Ft. per second* | *Feet.* | *Sec.-feet.* |
| January 8 | Bear Creek | Wallowa | 29.2 | 33.5 | 2.54 | | 75.2 |
| March 31 | do | do | 30.5 | 34.6 | 1.56 | | 54.5 |
| May 19 | do | do | 35.5 | 66.8 | 4.56 | | 305 |
| September 18 | do | do | | | | | .5 |
| November 9 | do | do | 19.3 | 14.9 | .81 | | 12.1 |
| November 5 | Birch Creek | Pendleton | 11.3 | 4.4 | .77 | | 3.4 |
| December 23 | do | do | 14.5 | 10.1 | 2.40 | | 24.2 |
| March 3 | Burnt River | Huntington | 42.8 | 53.2 | 3.69 | | 196 |
| March 24 | do | do | 43.5 | 96.5 | 4.07 | | 393 |
| September 14 | do.[a] | do | | | | | |

[a] Dry for about two months.

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*Miscellaneous discharge measurements made in Columbia River drainage basin in Oregon in 1905*—Continued.

| Date. | Stream. | Locality. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | | *Feet.* | *Square feet.* | *Ft. per second.* | *Feet.* | *Sec.-feet.* |
| November 22 | Burnt River | Huntington | 27 | 17.4 | 1.94 | | 33.9 |
| June 10 | Canyon Creek | Canyon City | 26 | 18.8 | 2.63 | | 49.4 |
| August 3 | Crescent Creek | Outlet Crescent Lake | 26 | 29 | 2.96 | | 85.8 |
| April 15 | Crooked River | NE. ¼ SW. ¼ sec. 5, T. 17 S., R. 17 E., Willamette meridian. | 83 | 287 | 2.19 | | 628 |
| April 18 | do | Forest | 90 | 301 | 2.45 | | 737 |
| May 19 | do | do | 85 | 162 | 1.67 | | 270 |
| June 10 | do | do | 24 | 23 | 1.35 | | 54 |
| August 11 | do | Prineville | 17 | 5.6 | 1.67 | | 9.4 |
| November 10 | do | do | 26 | 16.5 | 3.09 | | 51 |
| December 3 | do | Forest | 55 | 75 | 1.05 | | 79 |
| March 4 | Deschutes River | B. West's farm | 107 | 658 | 3.16 | | 2,080 |
| May 26 | do | Royce's ranch | 22.5 | 27 | 2.98 | | 80.4 |
| May 28 | do | Black Rock Ford | 73 | 81.9 | 2.40 | | 197 |
| June 27 | do | Royce's ranch | 23 | 21.5 | 2.13 | | 45.8 |
| Do | do | Black Rock Ford | 73 | 80.4 | 1.92 | | 154 |
| August 3 | do | Royce's ranch | 20 | 12.1 | 1.28 | | 15.4 |
| October 28 | do | SW. ¼ SW. ¼ sec. 31, T. 19 S., R. 11 E. | 106 | 584 | 2.59 | | 1,501 |
| November 17 | do | B. West's farm | 106 | 574 | 2.63 | | 1,460 |
| December 10 | do | do | 106 | 575 | 2.39 | | 1,375 |
| April 26 | East Fork of Deschutes River. | ½ mile below gaging station at Odell. | 44 | 34.8 | 1.78 | | 68.4 |
| April 29 | do | do | 43 | 36.8 | 1.78 | | 65.7 |
| June 25 | do | do | 43 | 33 | 1.51 | | 50 |
| Do | do | do | 43 | 33 | 1.33 | | 44 |
| March 5 | Deschutes Irrigation and Power Company's flume. | Near Bend | 5.3 | 5 | 4.50 | | 22.5 |
| June 10 | John Day River | John Day City | 30 | 81.4 | 3.30 | | 269 |
| September | McKay Creek | Pendleton | | | | | Dry. |
| November 16 | do | do | 14.2 | 5.8 | .71 | | 4.1 |
| December 23 | do | do | 38 | 85.7 | 1.02 | | 87.1 |
| September 20 | Minam River | At mouth near Elgin | 62.5 | 56.7 | 1.09 | | 61.9 |
| April 16 | Ochoco River | Prineville | 21 | 21.4 | 2.44 | | 52.2 |
| May 18 | do | do | 37 | 28.7 | 1.74 | | 50 |
| December 3 | do | do | 12 | 5.5 | .76 | | 4.2 |
| May 28 | Odell Lake Outlet | Odell Lake | 45 | 54.5 | 2.18 | | 119 |
| June 26 | do | do | 45 | 49.4 | 1.84 | | 90.8 |
| August 3 | do | do | 38 | 22.7 | 1.88 | | 42.6 |
| September 12 | Owyhee River | Wilson's ranch, Owyhee | 20 | 4.6 | 1.04 | | 4.8 |
| October 13 | do | do | 29.5 | 12.5 | 1.10 | | 13.7 |
| March 8 | Pauline Creek | Rosland | 8 | 5.5 | 2.22 | | 12.1 |
| May 24 | do | do | 7 | 4.9 | 1.62 | | 8 |
| June 24 | do | do | 7 | 3.4 | 1.12 | | 3.8 |
| October 25 | Quigley Creek | 3 miles from Hailey, Idaho. | 4.9 | 1.72 | 1.69 | | 2.91 |
| October 12 | Sandy | Salmon River post-office | 92.5 | 322 | 4.35 | 1.82 | 1,400 |
| March 17 | Satas | Alfalfa | 38 | 103 | 1.91 | | 197 |
| April 2 | do | do | 64 | 100 | 2.25 | 1.52 | 225 |
| October 3 | Silver Creek | Thompson's Valley | 12.5 | 8.4 | 1.31 | | 11 |
| December 4 | Squaw Creek | Sisters, above diversions | 30 | 29 | 1.67 | | 49 |
| December 5 | do | do | 31 | 30 | 1.69 | | 50 |

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*Miscellaneous discharge measurements made in Columbia River drainage basin in Oregon in 1905*—Continued.

| Date. | Stream. | Locality. | Width. | Area of section. | Mean velocity. | Gage height. | Discharge. |
|---|---|---|---|---|---|---|---|
| | | | *Feet.* | *Square feet.* | *Ft. per second.* | *Feet.* | *Second-feet.* |
| February 8 | Tumallo Creek | Bend | 26 | 37.6 | 3.17 | ..... | 120 |
| March 6 | ....do | ....do | 26 | 36.9 | 3.17 | ..... | 117 |
| June 21 | ....do | ....do | 25 | 39 | 3.44 | ..... | 134 |
| August 10 | ....do | ....do | 18 | 8.9 | 1.18 | ..... | 10.6 |
| November 26 | ....do | ....do | 24 | 32 | 3.00 | ..... | 97 |
| December 6 | ....do | ....do | 25 | 33 | 2.11 | ..... | 70 |
| September 28 | Umatilla River | Fosters | 62 | 45.7 | .42 | ..... | 19 |
| October 2 | ....do | ....do | 62 | 50.2 | .65 | 1.00 | 32.6 |
| October 5 | ....do | ....do | 61.8 | 44.8 | .42 | .87 | 18.5 |
| October 10 | ....do | ....do | 66 | 55.2 | .78 | 1.09 | 43 |
| October 18 | ....do | ....do | 69.4 | 60.5 | .95 | 1.17 | 57.6 |
| October 24 | ....do | ....do | 69 | 60.3 | .83 | 1.15 | 50.1 |
| October 26 | ....do | ....do | 70 | 63.9 | .93 | 1.18 | 59.7 |
| October 31 | ....do | ....do | 71.5 | 65.4 | 1.05 | 1.22 | 68.5 |
| August 9 | ....do | Below Echo, in sec. 16, T. 4, R. 28 E. | 19.5 | 22.6 | .73 | ..... | 16.5 |
| September 30 | ....do | ....do | 17.3 | 22.1 | .82 | ..... | 18.1 |
| September 19 | Wallowa River | Wallowa Falls above Wallowa Lake. | 21 | 21 | 1.57 | ..... | 33 |
| November 16 | Wild Horse Creek | Rug's ranch, Pendleton | 3.2 | .9 | .51 | ..... | .46 |
| December 23 | ....do | ....do | 3 | .96 | 1.77 | ..... | 1.7 |
| December 14 | South Fork of Yamhill River. | Sheridan | 122 | 428 | 1.36 | ..... | 583 |

## PUGET SOUND DRAINAGE BASIN.

For convenience in arrangement, the smaller rivers which have their headwaters on the western slope of the Cascade Range and which flow into Puget Sound north of Seattle have been grouped as the Puget Sound drainage.

### WHITE RIVER DRAINAGE BASIN.

White River has its source near Mount Rainier and flows into Puget Sound near Seattle, Wash. Cedar River is a tributary of White River.

#### CEDAR RIVER NEAR RAVENSDALE, WASH.

This station was established September 27, 1902, by T. A. Noble. It is located at the intake of the Seattle waterworks and is 15 miles below Cedar Lake, 4 miles from the Northern Pacific Railway at Ravensdale, and 6 miles from the Columbia and Puget Sound Railway at Maple Valley.

The channel is straight. The right bank is steep; the left bank has a sloping gravelly beach. The bed is permanent, rocky near the right bank, and of sand and gravel near the left bank.

Gagings at this station are made at two points. The first is 142 feet below the dam, where the cross section is small, the current rapid, and conditions suitable for gaging at stages below 1 foot on the gage. The measurements at this point are made from a cable. The initial point for soundings is on the right bank. To the discharge measurements made below the dam should be added the amount of water flowing into the gravity system which supplies the city of Seattle. This varies from 34 to 37 second-feet. The discharge of this

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pipe line was measured during the winter of 1901–2 by T. A. Noble, and the results have been published in volume 49, page 112, Transactions of the American Society of Civil Engineers.

At all stages of the river above 1 foot on the gage the measurements are made from a cable located 600 feet above the dam, at a point where the cross section is large and suitable for gaging the higher stages of the river. The initial point for soundings is a spike driven into the top of a hemlock stump about 12 inches in diameter near the edge of the water.

The gage is a plain staff, to which is attached a hook gage and vernier reading to thousandths. When this gage is at zero the hook is level with the crest of the dam. It is fastened securely to the head-gates above the dam, and during 1905 was read daily by George Landsburg. The bench mark is the crest of the dam. The elevation, from city levels, of the south end is 535.831 feet and of the north end 535.840 feet.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

**Description:** 100, pp 463–464; 135, pp 276–277.
**Discharge:** 100, p 464; 135, p 277.
**Discharge, monthly:** 100, p 465; 135, p 278.
**Gage heights:** 100, p 464; 135, p 277.
**Rating table:** 100, p 465; 135, p 278.

*Daily gage height, in feet, of Cedar River near Ravensdale, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.53 | 1.30 | 0.93 | 1.27 | 1.04 | 1.72 | 1.01 | 0.67 | 0.58 | 0.50 | 1.06 | 1.20 |
| 2 | 1.64 | 1.19 | 1.41 | 1.22 | 1.07 | 1.64 | .98 | .67 | .58 | .71 | .98 | 1.32 |
| 3 | 1.71 | 1.72 | 1.76 | 1.17 | 1.06 | 1.70 | .96 | .67 | .57 | 1.53 | .97 | 1.36 |
| 4 | 1.72 | 1.58 | 1.79 | 1.07 | 1.02 | 1.93 | .93 | .67 | .57 | 1.49 | .98 | 1.38 |
| 5 | 1.64 | 1.51 | 1.73 | 1.05 | .99 | 1.81 | .91 | .66 | .56 | 1.70 | .94 | 1.40 |
| 6 | 1.50 | 1.48 | 1.63 | 1.06 | .98 | 1.71 | .88 | .65 | .56 | 1.88 | .90 | 1.38 |
| 7 | 1.35 | 1.47 | 1.51 | 1.09 | 1.02 | 1.69 | .86 | .65 | .54 | 1.78 | .90 | 1.43 |
| 8 | 1.30 | 1.43 | 1.47 | 1.09 | .91 | 1.58 | .85 | .64 | .55 | 1.98 | .87 | 1.44 |
| 9 | 1.21 | 1.40 | 1.44 | 1.08 | 1.25 | 1.51 | .81 | .65 | .54 | 1.82 | .83 | 1.40 |
| 10 | 1.14 | 1.38 | 1.48 | 1.06 | 1.14 | 1.45 | .78 | .64 | .54 | 1.69 | .78 | 1.36 |
| 11 | 1.08 | 1.32 | 1.47 | 1.08 | 1.11 | 1.36 | .77 | .64 | .54 | 1.50 | .76 | 1.28 |
| 12 | 1.04 | 1.28 | 1.48 | 1.05 | 1.06 | 1.31 | .77 | .63 | .54 | 1.39 | .76 | 1.24 |
| 13 | .96 | 1.25 | 1.38 | 1.04 | 1.15 | 1.18 | .76 | .61 | .59 | 1.35 | .74 | 1.17 |
| 14 | .99 | 1.18 | 1.27 | 1.08 | 1.29 | 1.12 | .84 | .62 | .58 | 1.27 | .72 | 1.14 |
| 15 | .95 | .97 | 1.17 | 1.06 | 1.46 | 1.09 | .77 | .60 | .57 | 1.32 | .72 | 1.12 |
| 16 | .92 | .73 | 1.08 | 1.05 | 1.47 | 1.05 | .77 | .61 | .57 | 1.26 | .72 | 1.09 |
| 17 | .89 | .69 | 1.05 | 1.04 | 1.44 | .99 | .81 | .63 | .56 | 1.26 | .71 | 1.27 |
| 18 | .88 | .71 | 1.04 | 1.03 | 1.37 | .97 | .79 | .61 | .56 | 1.24 | .74 | 1.34 |
| 19 | .86 | .76 | 1.05 | 1.08 | 1.29 | .94 | .77 | .59 | .57 | 1.17 | 1.15 | 1.38 |
| 20 | .87 | .74 | 1.10 | 1.46 | 1.25 | .98 | .75 | .58 | .58 | 1.11 | 1.10 | 1.42 |
| 21 | .86 | .77 | 1.17 | 1.51 | 1.32 | .95 | .73 | .58 | .57 | 1.07 | 1.04 | 1.38 |
| 22 | .86 | .74 | 1.26 | 1.49 | 1.42 | .92 | .72 | .58 | .55 | 1.03 | 1.02 | 1.32 |
| 23 | .88 | .76 | 1.30 | 1.47 | 1.91 | .90 | .71 | .57 | .53 | .99 | .98 | 1.28 |
| 24 | .99 | .78 | 1.50 | 1.47 | 2.74 | .89 | .71 | .50 | .54 | 1.02 | .94 | 1.35 |
| 25 | 1.03 | .77 | 1.55 | 1.54 | 2.46 | .92 | .70 | .56 | .60 | 1.47 | 1.30 | 1.37 |
| 26 | 1.02 | .76 | 1.57 | 1.55 | 2.13 | .91 | .70 | .56 | .63 | 1.49 | 1.60 | 1.71 |
| 27 | 1.40 | .74 | 1.61 | 1.46 | 1.95 | 1.00 | .69 | .56 | .60 | 1.41 | 1.65 | 1.79 |
| 28 | 1.66 | .83 | 1.54 | 1.39 | 1.96 | 1.22 | .69 | .58 | .60 | 1.29 | 1.54 | 1.65 |
| 29 | 1.69 | ..... | 1.46 | 1.28 | 1.91 | 1.19 | .69 | .58 | .61 | 1.23 | 1.39 | 1.53 |
| 30 | 1.55 | ..... | 1.33 | 1.18 | 1.80 | 1.06 | .68 | .58 | .60 | 1.15 | 1.29 | 1.49 |
| 31 | 1.43 | ..... | 1.26 | ..... | 1.75 | ..... | .68 | .58 | ..... | 1.09 | ..... | 1.39 |

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## SNOHOMISH RIVER DRAINAGE BASIN.

Snoqualmie and Skykomish rivers unite to form the Snohomish, which flows into Puget Sound about 10 miles beyond the junction, near Everett, Wash. The Stilaguamish lies north of the Skykomish and has a parallel course.

### SOUTH FORK OF SKYKOMISH RIVER NEAR INDEX, WASH.

This station was established October 6, 1902, by T. A. Noble, and was discontinued September 30, 1905. It is located about 2 miles above Index and about 300 feet from the railroad track.

The channel is straight for 500 feet above and 300 feet below the station. Both banks are of solid rock and not liable to overflow. The bed of the stream is of sand and gravel, not liable to change except near the left bank, where the sand shifts at high water. This does not cause any important change in the cross section. This station is 300 feet upstream from Sunset Falls, where the river plunges down a solid granite ledge with a slope of about two horizontal to one vertical. The ledge answers the purpose of a spillway in regulating the flow of the river at the gaging station, since the water has a free discharge and a permanent bed just below the station.

Discharge measurements are made by means of a cable and car. The initial point for for soundings is on the left bank at a plug driven in the solid rock 10 feet from the edge of the stream at low water.

A staff gage is fastened to the solid rock A hook gage is used for reading to hundredths of a foot. During 1905 the gage was read once each day by Louis G. Heybrook. The bench mark is a cross cut in the rock about 6 feet above low water and 40 feet downstream from the gage; elevation, 9.232 feet above the datum of the gage and 679.158 feet above sea level, as obtained from the Great Northern Railway.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 85, p 222; 100, pp 471–472; 135, pp 278–279.
Discharge: 85, p 223.
Discharge, monthly: 100, p 474; 135, p 280.
Gage heights: 85, p 223; 100, pp 472–473; 135, p 279.
Rating table: 100, p 473; 135, p 280.

*Daily gage height, in feet, of South Fork of Skykomish River near Index, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.55 | 2.93 | 5.72 | 3.14 | 3.53 | 7.02 | 3.71 | 1.83 | 1.51 |
| 2 | 4.72 | 2.71 | 6.85 | 3.07 | 3.2 | 6.21 | 3.45 | 1.81 | 1.34 |
| 3 | 5.25 | 2.78 | 7.2 | 3.02 | 3.24 | 8.1 | 3.31 | 1.66 | 1.33 |
| 4 | 5.4 | 2.6 | 7.1 | 2.94 | 3.21 | 7.45 | 3.28 | 1.62 | 1.28 |
| 5 | 5.43 | 2.46 | 6.41 | 3.27 | 3.6 | 5.7 | 3.25 | 1.62 | 1.15 |
| 6 | 3.88 | 2.15 | 5.72 | 3.45 | 3.87 | 5.56 | 3.19 | 1.6 | 1.12 |
| 7 | 3.55 | 2.38 | 5.21 | 3.91 | 4.48 | 5.61 | 3.02 | 1.58 | 1.08 |
| 8 | 3.21 | 2.15 | 5.21 | 4.39 | 5.66 | 5.98 | 2.92 | 1.53 | 1.34 |
| 9 | 2.98 | 2.04 | 5.62 | 3.75 | 5.31 | 6.21 | 3.04 | 1.56 | 1.86 |
| 10 | 3.8 | 1.97 | 6.1 | 3.22 | 4.44 | 6.1 | 2.98 | 1.54 | 1.62 |
| 11 | 2.52 | 1.66 | 6.81 | 3.21 | 4.02 | 5.81 | 2.83 | 1.48 | 1.43 |
| 12 | 2.38 | 1.6 | 5.28 | 3.42 | 3.89 | 5.48 | 2.43 | 1.43 | 1.41 |
| 13 | 2.23 | 1.64 | 4.72 | 3.74 | 3.54 | 5.45 | 2.35 | 1.41 | 1.45 |
| 14 | 2.2 | 1.63 | 4.46 | 3.72 | 6.6 | 5.38 | 2.61 | 1.4 | 1.34 |
| 15 | 2.18 | 1.61 | 4.49 | 3.45 | 5.21 | 4.8 | 2.48 | 1.98 | 1.32 |
| 16 | 2.18 | 1.58 | 4.5 | 3.31 | 4.72 | 4.13 | 2.5 | 4.43 | 1.31 |
| 17 | 2.19 | 1.52 | 4.47 | 3.21 | 5.37 | 4.23 | 2.48 | 4.74 | 1.56 |
| 18 | 2.12 | 1.45 | 4.71 | 3.47 | 4.42 | 4.32 | 2.29 | 3.16 | 2.21 |

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*Daily gage height, in feet, of South Fork of Skykomish River near Index, Wash., for 1905.*—Continued.

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 19 | 2.22 | 2.12 | 4.51 | 4.0 | 4.25 | 4.29 | 2.22 | 2.32 | 2.0 |
| 20 | 2.2 | 2.4 | 4.34 | 4.62 | 4.14 | 4.41 | 2.26 | 2.17 | 3.81 |
| 21 | 2.08 | 3.1 | 4.61 | 4.63 | 4.09 | 4.35 | 2.34 | 1.9 | 2.74 |
| 22 | 2.18 | 4.48 | 4.48 | 5.12 | 4.25 | 4.12 | 2.31 | 1.68 | 2.45 |
| 23 | 2.31 | 5.0 | 4.48 | 5.52 | 4.32 | 3.91 | 2.19 | 1.53 | 2.7 |
| 24 | 3.02 | 5.4 | 4.92 | 6.13 | 4.81 | 3.81 | 2.12 | 1.45 | 2.85 |
| 25 | 3.2 | 7.75 | 4.94 | 6.58 | 4.56 | 3.49 | 2.0 | 1.21 | 2.9 |
| 26 | 2.92 | 5.12 | 4.73 | 6.22 | 4.78 | 4.06 | 1.94 | 1.18 | 6.55 |
| 27 | 6.18 | 5.21 | 4.2 | 6.2 | 5.38 | 4.82 | 1.88 | 1.23 | 4.8 |
| 28 | 5.95 | 5.58 | 4.15 | 4.5 | 5.69 | 4.51 | 2.03 | 1.19 | 3.82 |
| 29 | 4.10 | ..... | 3.81 | 3.98 | 5.89 | 4.34 | 1.98 | 1.25 | 3.76 |
| 30 | 3.78 | ..... | 3.48 | 3.62 | 6.41 | 3.81 | 1.95 | 1.28 | 3.85 |
| 31 | 3.31 | ..... | 3.24 | ..... | 7.12 | ..... | 1.91 | 2.0 | ..... |

## SNOQUALMIE RIVER NEAR SNOQUALMIE FALLS, WASH.

This station was originally established by T. A. Noble September 14, 1902, and was discontinued September 30, 1905. The gage was originally located below the falls, but was destroyed by the flood of December 1, 1902. November 2, 1902, another gage was placed about 3 miles above Snoqualmie Falls post-office.

The right bank is high and never overflows; the left bank overflows at extreme high water. The bed of the stream is of gravel and sand and is not liable to shift. The station is located below the junction of the north, south, and middle forks of Snoqualmie River. At Snoqualmie Falls, about 4 miles below this station, the river flows over a precipice 268 feet high. Above the falls the Snoqualmie Falls Power Company has built a dam and water-power plant. The slack water from this dam reaches back from the falls about 3 miles, and probably affects the flow of the river slightly at the gaging station. This is the only possible location for a gaging station which will include all three forks of the river.

Discharge measurements are made by means of a cable and car. The initial point for soundings is a spike driven into a large maple stump on the right bank, about 4 feet above the ground.

The present gage, established January 7, 1903, is in two sections. During 1905 the gage was read once each day by E. C. Reinig. The bench mark is the initial point for soundings; elevation, 27.83 feet above the datum of the gage.

Information in regard to this station is contained in the following Water-Supply Papers of the United States Geological Survey:

Description: 85, pp 220–221; 100, pp 468–469; 135, p 281.
Discharge: 85, p 221; 100, p 469.
Discharge, monthly: 100, p 471; 135, p 284.
Gage heights: 85, pp 221–222; 100, pp 469–470; 135, p 282.
Rating table: 100, p 470; 135, p 283.



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*Daily gage height, in feet, of Snoqualmie River near Snoqualmie Falls, Wash., for 1905.*

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.93 | 2.96 | 6.23 | 3.0 | 3.01 | 6.13 | 2.71 | 1.24 | 1.05 |
| 2 | 5.73 | 2.75 | 7.85 | 2.97 | 3.67 | 5.1 | 2.64 | 1.19 | .93 |
| 3 | 6.15 | 2.63 | 6.54 | 2.84 | 2.59 | 7.37 | 2.51 | 1.13 | .85 |
| 4 | 4.77 | 2.44 | 5.6 | 2.06 | 2.53 | 6.7 | 2.44 | 1.09 | .83 |
| 5 | 4.21 | 2.31 | 5.13 | 3.28 | 2.61 | 6.17 | 2.37 | 1.05 | .79 |
| 6 | 3.55 | 2.2 | 4.46 | 3.31 | 2.97 | 5.45 | 2.29 | 1.0 | .75 |
| 7 | 3.33 | 2.23 | 4.31 | 3.59 | 4.02 | 5.2 | 2.2 | .99 | .71 |
| 8 | 3.05 | 2.26 | 3.98 | 3.23 | 4.38 | 4.99 | 2.19 | 1.0 | .92 |
| 9 | 2.8 | 2.19 | 4.21 | 3.02 | 5.06 | 4.92 | 2.21 | .98 | 1.02 |
| 10 | 2.61 | 2.11 | 4.5 | 2.85 | 5.0 | 4.87 | 2.12 | .96 | .98 |
| 11 | 2.43 | 2.05 | 4.21 | 2.81 | 5.23 | 4.61 | 1.97 | .94 | .9 |
| 12 | 2.16 | 1.87 | 3.94 | 2.79 | 6.62 | 3.92 | 1.82 | .9 | .85 |
| 13 | 2.0 | 1.63 | 3.67 | 3.24 | 7.21 | 3.75 | 1.74 | .85 | 1.1 |
| 14 | 2.19 | 1.6 | 3.56 | 3.12 | 7.42 | 3.41 | 1.98 | .8 | 1.25 |
| 15 | 2.27 | 1.58 | 3.4 | 2.97 | 5.29 | 3.32 | 2.21 | .82 | 1.11 |
| 16 | 2.38 | 1.55 | 3.49 | 2.84 | 4.41 | 3.16 | 2.52 | 1.45 | 1.23 |
| 17 | 2.35 | 1.54 | 3.58 | 3.19 | 4.22 | 3.09 | 2.58 | 4.41 | 1.45 |
| 18 | 2.33 | 1.84 | 3.4 | 3.47 | 4.12 | 3.01 | 2.34 | 2.62 | 2.08 |
| 19 | 2.2 | 2.63 | 3.91 | 3.04 | 4.02 | 2.93 | 2.29 | 2.31 | 1.85 |
| 20 | 2.19 | 3.22 | 4.1 | 3.89 | 3.96 | 2.94 | 2.17 | 1.87 | 2.61 |
| 21 | 2.18 | 4.3 | 4.35 | 4.23 | 3.81 | 2.92 | 2.03 | 1.82 | 2.12 |
| 22 | 2.21 | 4.43 | 4.56 | 4.45 | 4.61 | 2.91 | 1.92 | 1.72 | 1.8 |
| 23 | 2.45 | 4.61 | 4.61 | 4.97 | 5.3 | 2.89 | 1.8 | 1.56 | 1.71 |
| 24 | 4.1 | 6.2 | 4.79 | 5.21 | 8.05 | 2.9 | 1.73 | 1.42 | 1.92 |
| 25 | 3.82 | 5.69 | 4.69 | 5.26 | 7.01 | 2.91 | 1.58 | 1.36 | 2.0 |
| 26 | 4.67 | 5.20 | 4.5 | 4.92 | 5.68 | 2.99 | 1.45 | 1.21 | 5.62 |
| 27 | 5.82 | 4.27 | 4.34 | 4.92 | 5.63 | 3.32 | 1.43 | 1.16 | 4.27 |
| 28 | 5.89 | 4.36 | 3.92 | 3.63 | 5.6 | 3.21 | 1.41 | 1.02 | 3.35 |
| 29 | 4.53 | ..... | 3.61 | 3.42 | 5.57 | 2.96 | 1.38 | 1.07 | 3.27 |
| 30 | 3.97 | ..... | 3.29 | 3.0 | 5.53 | 2.81 | 1.32 | 1.09 | 3.16 |
| 31 | 3.34 | ..... | 3.13 | ..... | 5.5 | ..... | 1.27 | 1.06 | ..... |

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# INDEX.


Page.

Acknowledgments ..... 12
Acre-foot, definition of ..... 4
Albany, Oreg.,
  Willamette River at:
    description ..... 223
    discharge ..... 223
    gage heights ..... 223
Alfalfa, Oreg.,
  Satas River near:
    discharge ..... 229
Allen ditch at—
  Echo, Oreg.:
    description ..... 194
    discharge ..... 194-195
    discharge of wasteway of ..... 195
American Falls, Idaho,
  Snake River above:
    discharge ..... 96
Arcadia, Oreg.,
  Emerson wasteway near:
    discharge ..... 120
  Lockett's Gulch wasteway near:
    discharge ..... 120
Arlington, Oreg.,
  Rock Creek near:
    description ..... 206
    discharge ..... 206
    discharge, monthly ..... 207
    gage heights ..... 206-207
    rating table ..... 207
  Willow Creek near:
    description ..... 202
    discharge ..... 202
    discharge, monthly ..... 203
    gage heights ..... 202
    rating table ..... 203
Asotin Creek near—
  Asotin, Wash.:
    description ..... 167, 168
    gage heights ..... 168, 169
Baker City, Oreg.,
  Powder River near:
    description ..... 148
    discharge ..... 149
    discharge, monthly ..... 150
    gage heights ..... 149
    rating table ..... 150
Barton, Oreg.,
  Clackamas River near:
    description ..... 228
    discharge ..... 228
    gage heights ..... 228
Bear Creek near—
  Wallowa, Oreg.:
    discharge ..... 228
Becker Creek Logan ditch above Vale, Oreg.:
  discharge ..... 147
Beitle ditch near—
  Hermiston, Oreg.:
    description ..... 199
    discharge ..... 199
Bend, Oreg.,
  Central Oregon canal near:
    description ..... 216
    discharge ..... 216
    discharge, monthly ..... 217
    gage heights ..... 216
    rating table ..... 217
  Columbia Southern canal near:
    discharge ..... 219
  Deschutes River near:
    description ..... 208
    discharge ..... 208
    discharge, monthly ..... 209
    gage heights ..... 208-209
    rating table ..... 209
  Pilot Butte canal near:
    description ..... 217
    discharge ..... 217
    discharge, monthly ..... 219
    gage heights ..... 218
    rating table ..... 218
  Tumalo Creek near:
    discharge ..... 230
Benton Water Company's canal near—
  Kiona, Wash.:
    discharge ..... 62
    gage heights ..... 62
    headworks location ..... 53, 62
Big Bend ditch at—
  Joseph, Oreg.:
    description ..... 165
    discharge ..... 165
    gage heights ..... 166
Big Blackfoot River near—
  Bonner, Mont.:
    description ..... 19
    discharge ..... 19
    discharge, monthly ..... 21
    gage heights ..... 20
    rating table ..... 20
Big Lost River near—
  Chilly, Idaho:
    description ..... 110
    discharge ..... 110
    discharge, monthly ..... 112




Digitized by Google

Big Lost River near— Page.
Chilly, Idaho—Continued.
gage heights ..... 111
rating table ..... 111
Mackay, Idaho:
description ..... 108
discharge ..... 108
discharge, monthly ..... 110
gage heights ..... 109
rating table ..... 109
Big Wood River near—
Gimlet, Idaho:
description ..... 112
discharge ..... 112
gage heights ..... 113
Shoshone, Idaho:
description ..... 113
gage heights ..... 113
Birch Creek near—
Pendleton, Oreg.:
discharge ..... 228
Bitterroot River near—
Grantsdale, Mont.:
description ..... 21
discharge ..... 22
discharge, monthly ..... 23
gage heights ..... 22
rating table ..... 23
Blackfoot River near—
Presto, Idaho:
description ..... 106
discharge ..... 106
discharge, monthly ..... 107–108
gage heights ..... 106–107
rating table ..... 107
Boise River, Idaho:
description ..... 91
near Highland, Idaho:
description ..... 121
discharge ..... 122
discharge, daily ..... 123
discharge, monthly ..... 123
gage heights ..... 122
Bonner, Mont.,
Big Blackfoot River near:
description ..... 19
discharge ..... 19
discharge, monthly ..... 21
gage heights ..... 20
rating table ..... 20
Bowman ditch at—
Umatilla, Oreg.:
description ..... 201
discharge ..... 201
Broadgauge canal near—
North Yakima, Wash.:
description ..... 73
discharge ..... 73
gage heights ..... 73
head works location ..... 54
Brosnan ditch near—
Ontario, Oreg.:
discharge ..... 137
Brownwell ditch at—
Umatilla, Oreg.:
description ..... 201
discharge ..... 201

Bully Creek at and above— Page.
Vale, Oreg.:
description ..... 137–138, 140
discharge ..... 138, 140
discharge, monthly ..... 139
gage heights ..... 138–139, 141
rating table ..... 139
Burnt River near—
Huntington, Oreg.:
discharge ..... 228, 229
Canyon City, Oreg.,
Canyon Creek, near:
discharge ..... 229
Canyon Creek near—
Canyon City, Oreg.:
discharge ..... 229
Carey, Idaho,
Little Wood River near:
description ..... 113–114
discharge ..... 114
gage heights ..... 114
Carmichael ditch at—
Prineville, Oreg.:
discharge ..... 219
Cascade canal near—
Thorp, Wash.:
discharge ..... 54
gage heights ..... 55
head works location ..... 53, 54
Cashmere, Wash.,
Wenache River at:
description ..... 40
discharge ..... 41
discharge, monthly ..... 42
gage heights ..... 41
rating table ..... 42
Cedar River near—
Ravensdale, Wash.:
description ..... 230–231
gage heights ..... 231
Central Oregon canal near—
Bend, Oreg.:
description ..... 216
discharge ..... 216
discharge, monthly ..... 217
gage heights ..... 216
rating table ..... 217
Chelan Lake at—
Chelan, Wash.:
gage heights ..... 37
Chelan River below—
Lake Chelan, Wash.:
description ..... 38
discharge ..... 39
discharge, monthly ..... 40
gage heights ..... 39
rating table ..... 39
Chelan River basin:
description ..... 37
Chilly, Idaho,
Big Lost River near:
description ..... 110
discharge ..... 110
discharge, monthly ..... 112
gage heights ..... 111
rating table ..... 111


Digitized by Google

Clackamas River near— Page.
Barton, Oreg.:
description 228
discharge 228
gage heights 228
Clark canal near—
North Yakima, Wash.:
description 68
discharge 68
gage heights 68
head works location 54, 68
Clark Fork at—
Priest River, Idaho:
description 15
discharge 15
discharge, monthly 16
gage heights 15
rating table 16
Clark Fork drainage basin:
description 14
Cleahum River near—
Roslyn, Wash.:
description 80-81
discharge 81
discharge, monthly 82
gage heights 81
rating table 82
Coeur d'Alene Lake at—
Couer d'Alene, Idaho:
description 24
gage heights 25
Cold Springs near—
Hermiston, Oreg.:
discharge 201
Cole's ditch near—
Dell, Oreg.:
discharge 146
Columbia River near—
Julia, Wash.:
description 12
gage heights 13
Pasco, Wash.:
description 13-14
gage heights 14
Columbia River basin:
description 12
Columbia Southern canal near—
Bend, Oreg.:
discharge 219
Company ditch above—
Vale, Oreg.:
discharge 146
Company ditch near—
Wallowa, Oreg.:
description 166
discharge 166
discharge, monthly 167
gage heights 166-167
Computation, rules for 4-5
Cow Creek near—
Keystone, Wash.:
description 175
discharge 175
gage heights 175-176
Cow Hollow wasteway near— Page.
Owyhee, Oreg.:
discharge 120
Cox canal near—
North Yakima, Wash.:
discharge 77
head works location 54
Crescent Creek at—
Crescent Lake outlet:
discharge 229
Crooked River near—
Forest, Oreg.:
discharge 299
Prineville, Oreg.:
discharge 229
Sec. 5, T. 17 S., R. 17 E.:
discharge 229
Current meters, classes of 8
methods of using 9 10
Dell, Oreg.,
Cole's ditch near:
discharge 146
Willow Creek near:
description 143-144
discharge 144
discharge, monthly 146
gage heights 144-145
rating table 145
Deschutes Irrigation and Power Company's flume near—
Bend, Oreg.:
discharge 229
Deschutes River basin:
description 207
Deschutes River near—
Bend, Oreg.:
description 208
discharge 208
discharge, monthly 209
gage heights 208-209
rating table 209
Black Rock Ford:
discharge 229
Lava, Oreg.:
description 212
discharge 212
discharge, monthly 213
gage heights 212-213
rating table 213
Royce's ranch:
discharge 229
West's (B.) farm:
discharge 229
T. 19, R. 11 E.:
discharge 229
Deschutes River, East Fork near—
Odell, Oreg.:
description 210
discharge 210, 229
discharge, monthly 211
gage heights 210 211
rating table 211
Deschutes River, West Fork, near
Lava, Oreg.:
description 214


Digitized by Google

Deschutes River, West Fork, near— Page.
Lava, Oreg.—Continued.
discharge 214
discharge, monthly 215
gage heights 214-215
rating table 215
Deschutes River Valley,
Canals in:
station data 216-219
Dickey Prairie, Oreg.,
Molalla River at:
description 227
discharge 227
gage heights 227
Discharge, methods of measuring and computing 6-11
Drainage basins, list of 2-3
Easton, Wash.,
Kachess Lake near:
gage heights 78
Kachess River near:
description 78-79
discharge 79
discharge, monthly 80
gage heights 79
rating table 80
Echo, Oreg.,
Allen ditch at:
description 194
discharge 194-195
discharge of wasteway of 195
Gillette Springs outlet near:
discharge 201
Henrietta mill ditch at:
description 192
discharge 193
discharge of wasteway of 193
Hinkle ditch at:
description 195
discharge 196
Lisle (Charles) ditch at:
discharge 192
Lisle & Crane ditch near:
description 191
discharge 191
Maxwell ditch at:
description 197
discharge 197
discharge of wasteway of 197
Pioneer ditch at:
description 196
discharge 196
Unatilla River near:
discharge 230
Wilson & Co.'s ditch at:
description 194
discharge 194
Elberton, Wash.,
Palouse River at:
description 169-170
discharge 170
gage heights 170
Elgin, Oreg.,
Grande Ronde River near:
description 153
discharge 153
discharge, monthly 155
Elgin, Oreg.—Continued. Page.
Grand Ronde River near—
gage heights 154
rating table 154
Minam River near:
discharge 229
Wallowa River near:
description 161-162
discharge 162
discharge, monthly 163
gage heights 162
rating table 163
Ellensburg, Wash.,
Fogarty canal near:
discharge 77
head works location 83
Olsen canal near:
discharge 56
gage heights 56
head works location 53, 56
Town canal near:
discharge 56
gage heights 56
head works location 53, 55
Emerson wasteway near—
Arcadia, Oreg.:
discharge 120
Equivalents, table of 5-6
Fall River at—
Fremont, Idaho:
description 97
discharge 97
discharge, monthly 98-99
gage heights 97-98
rating table 98
Farmers and Citizens ditch near—
Joseph, Oreg.:
description 164
discharge 164
gage heights 164
Farmers' mill ditch at—
Pendleton, Oreg.:
description 190
discharge 190
gage heights 190
Faulkner (Patrick and Larry) ditches above—
Vale, Oreg.:
discharge 147
Findley's ditch near—
Rosland, Oreg.:
discharge 216
Fletcher wasteway near—
Owyhee, Oreg.:
discharge 139
Floats, use of, in measuring discharge 9
Fogarty canal near—
Ellensburg, Wash.:
discharge 77
head works location 53
Forest, Oreg.,
Crooked River near:
discharge 229
Fortune canal near—
North Yakima, Wash.:
description 67
discharge 67


Digitized by Google

Fortune canal near— Page.
North Yakima, Wash.—Continued.
gage heights ..... 67
head works location ..... 54, 67
Fosters, Oreg.,
Umatilla River near:
discharge ..... 230
Fowler canal near—
North Yakima, Wash.:
discharge ..... 59
gage heights ..... 60
head works location ..... 53, 59
Fremont, Idaho,
Fall River at:
description ..... 97
discharge ..... 97
discharge, monthly ..... 98–99
gage heights ..... 97–98
rating table ..... 98
Gaging stations, equipment of ..... 7
Gellerman & Frohman ditch above Vale, Oreg.:
description ..... 135
discharge ..... 135
Gibbon, Oreg.,
Umatilla River near:
description ..... 181–182
discharge ..... 182
discharge, monthly ..... 183
gage heights ..... 182–183
rating table ..... 183
Gillette Springs outlet near—
Echo, Oreg.:
discharge ..... 201
Gimlet, Idaho,
Big Wood River near:
description ..... 112
discharge ..... 112
gage heights ..... 113
Gleed canal near—
North Yakima, Wash.:
description ..... 69
discharge ..... 69
gage heights ..... 70
head works location ..... 54, 69
Goshen, Oreg.,
Coast Fork of Willamette River near:
description ..... 221
discharge ..... 221
gage heights ..... 222
Grande Ronde River near—
Elgin, Oreg.:
description ..... 153
discharge ..... 153
discharge, monthly ..... 155
gage heights ..... 154
rating table ..... 154
Hilgard, Oreg.:
description ..... 150–151
discharge ..... 151
discharge, monthly ..... 152
gage heights ..... 151–152
rating table ..... 152
Zindel, Wash.:
description ..... 155
gage heights ..... 155–156
Granger canal near— Page.
North Yakima, Wash.:
discharge ..... 77
head works location ..... 53
Granger ditch at—
Joseph, Oreg.:
description ..... 165
discharge ..... 165
gage heights ..... 165
Grantsdale, Mont.,
Bitterroot River near:
description ..... 21
discharge ..... 22
discharge, monthly ..... 23
gage heights ..... 22
rating table ..... 23
Gray ditch above—
Vale, Oreg.:
discharge ..... 147
Grosscup's canal near—
Kiona, Wash.:
description ..... 65
discharge ..... 65
gage heights ..... 65
head works location ..... 53, 65
Hailey, Oreg.:
Quigley Creek near:
discharge ..... 229
Halliday's bridge near Ontario, Oreg.,
Malheur River at:
description ..... 131
discharge ..... 132
discharge, monthly ..... 133
gage heights ..... 132
rating table ..... 133
Hangman Creek at and near—
Tekoa, Wash.:
description ..... 27–28, 29
discharge, daily ..... 29
gage heights ..... 28
Hangman Creek, North Fork, at—
Tekoa, Wash.:
description ..... 29–30
discharge ..... 30
gage heights ..... 30
Harris ditch above—
Vale, Oreg.:
discharge ..... 147
Hendricks Ferry, Oreg.,
McKenzie River at:
description ..... 222
discharge ..... 222
gage heights ..... 223
Henrietta mill ditch at—
Echo, Oreg.:
description ..... 192
discharge ..... 193
discharge of wasteway from ..... 193
Hermiston, Oreg.,
Beitle ditch near:
description ..... 199
discharge ..... 199
Cold Springs near:
discharge ..... 201
Hermiston ditch near:
description ..... 198
discharge ..... 198


Digitized by Google

Hermiston ditch near— Page.
Hermiston, Oreg.:
description 198
discharge 198
Highland, Idaho,
Boise River near:
description 121
discharge 122
discharge, daily 123
discharge, monthly 123
gage heights 122
Hilgard, Oreg.,
Grande Ronde River at:
description 150-151
discharge 151
discharge, monthly 152
gage heights 151-152
rating table 152
Hinkle ditch at—
Echo, Oreg.:
description 195
discharge 196
Homedale, Idaho,
Succor Creek near:
description 114-115
discharge 115
discharge, monthly 116
gage heights 115
Hood River at—
Winans City, Oreg.:
description 219-220
discharge 220
gage heights 220
Hooper, Wash.,
Palouse River at:
description 171
discharge 171
discharge, monthly 173
gage heights 172
rating table 172
Hope Mill ditch at—
Vale, Oreg.:
description 136
discharge 136
Horseshoe Irrigation Company's ditch at—
Yoakum, Oreg.:
description 191
Hubbard canal near—
North Yakima, Wash.:
discharge 59
gage heights 59
head works location 53, 59
Huntington, Oreg.,
Burnt River near:
discharge 228, 229
Hydrographers, list of 12
Hydrographic surveys, annual appropriations for 4
organization and scope of 1-4
Ice-covered streams, method of measuring flow of 10
Index, Wash.,
South Fork of Skykomish River near:
description 232
gage heights 232-233
Jasper, Oreg., Page.
Middle Fork of Willamette River at:
description 220
discharge 221
gage heights 221
Jefferson, Oreg.,
Santiam River at:
description 220
discharge 221
gage heights 220
"J. H." ditch—
Above Vale, Oreg.:
description 135
discharge 135
John Day River near—
John Day City:
discharge 29
McDonald, Oreg.:
description 303-304
discharge 304
discharge, monthly 307
gage heights 304-307
rating table 307
John Day River basin;
description 303
Joseph, Oreg.,
Big Bend ditch at:
description 165
discharge 165
gage heights 166
Farmers and Citizens' ditch near:
description 164
discharge 164
gage heights 164
Granger ditch at:
description 167
discharge 165
gage heights 165
Silver Lake ditch near:
description 163
discharge 163
gage heights 164
Wallowa River near:
description 156-157
discharge 157
discharge, monthly 159
gage heights 157-158
rating table 159
Wallowa Lake near:
description 176
discharge 176
Julia, Wash.,
Columbia River near:
description 12
gage heights 12
Kachess Lake near—
Easton, Wash.:
gage heights 78
Kachess River near—
Easton, Wash.:
description 78-79
discharge 79
discharge, monthly 80
gage heights 79
rating table 80


Digitized by Google

Kelly canal near— Page.
North Yakima, Wash.:
discharge 77
head works location 54
Kennewick canal near—
Kennewick, Wash.:
description 64
discharge 64
gage heights 64
head works location 53, 64
Keystone, Wash.,
Cow Creek near:
description 175
discharge 175
gage heights 175–176
Kiona, Wash.,
Benton Water Company's canal near:
discharge 62
gage heights 62
head works location 53, 62
Grosscup canal near:
description 65
discharge 65
gage heights 65
head works location 53, 65
Kiona canal near:
description 63
discharge 63
gage heights 63
head works location 53, 63
Kiona Water Company's canal near:
description 63
discharge 63
gage heights 64
head works location 53, 64
Yakima River near:
description 49–50
discharge 50
discharge, monthly 52
gage heights 51
rating table 51
Kiona canal near—
Kiona, Wash.:
description 63
discharge 63
gage heights 63
head works location 53, 63
Kiona Water Supply Company's canal near—
Kiona, Wash.:
description 63
discharge 63
gage heights 64
head works location 53, 63
Laswell canal near—
North Yakima, Wash.:
discharge 77
head works location 54
Lava, Oreg.,
Deschutes River near:
description 212
discharge 212
discharge, monthly 213
gage heights 212
rating table 213
West Fork of Deschutes River near:
description 214
Lava, Oreg.—Continued. Page.
West Fork of Deschutes River near:
discharge 214
discharge, monthly 215
gage heights 214–215
rating table 215
Linebarger ditch above—
Vale, Oreg.:
description 135
discharge 135
Lisle (Charles) ditch at—
Echo, Oreg.:
discharge 192
Lisle and Crane ditch near
Echo, Oreg.:
description 191
discharge 191
Little Wood River near—
Carey, Idaho:
description 113–114
discharge 114
gage heights 114
Little Spokane River near—
Spokane, Wash.:
description 31
gage heights 31
Locketts Gulch wasteway near—
Arcadia, Oreg.:
discharge 120
Logan ditch above—
Vale, Oreg.:
discharge 147
Loomis, Wash.:
Sinlahekin Creek near:
description 31–32
gage heights 32
Lower Scott canal near—
North Yakima, Wash.:
description 67
discharge 67
gage heights 68
head works location 54, 67
Lowery canal near—
North Yakima, Wash.:
description 68
discharge 69
gage heights 69
head works location 54, 68
Luckiamute River near—
Suver, Oreg.:
description 226
discharge 226
gage heights 227
Lyon, Idaho,
South Fork of Snake River near:
description 103–104
discharge 104
discharge, monthly 105
gage heights 104–105
rating table 105
McCormick canal near—
North Yakima, Wash.:
description 72
discharge 72
gage heights 72
head works location 54, 72


Digitized by Google

McDonald, Oreg., Page.
John Day River at:
description ... 203-204
discharge ... 204
discharge, monthly ... 205
gage heights ... 204-205
rating table ... 205
Mackay, Idaho,
Big Lost River near:
description ... 108
discharge ... 108
discharge, monthly ... 110
gage heights ... 109
rating table ... 109
McKay Creek near—
Pendleton, Oreg.:
discharge ... 229
McKenzie River at—
Hendricks Ferry, Oreg.:
description ... 222
discharge ... 222
gage heights ... 223
McLaughlin ditch above—
Vale, Oreg.:
description ... 134
discharge ... 134
McLaughlin's bridge near Vale Oreg.,
Malheur River at:
description ... 129
discharge ... 129
discharge, monthly ... 131
gage heights ... 130
rating table ... 130
Malheur, Oreg.,
Willow Creek near:
description ... 141
discharge ... 142
discharge, monthly ... 143
gage heights ... 142
rating table ... 143
Malheur Farmers' canal above Vale, Oreg.:
description ... 134
discharge ... 134
Malheur River, Oreg.:
description ... 91
near Ontario:
description ... 131
discharge ... 132
discharge, monthly ... 133
gage heights ... 132
rating table ... 133
near Vale:
description ... 126, 129
discharge ... 127, 129
discharge, daily ... 128
discharge, monthly ... 129, 131
gage heights ... 127-128, 130
rating table ... 130
near Westfall:
description ... 124
discharge ... 124
discharge, monthly ... 126
gage heights ... 125
rating table ... 125
Malheur River Valley, Oreg.,
ditches in:
station data ... 133-137
Malott, Wash., Page.
Salmon Creek near:
description ... 32-33
discharge ... 33
discharge, monthly ... 34
gage heights ... 33
rating table ... 34
Martin, Wash.,
Yakima River near:
description ... 43-44
discharge ... 44
discharge, monthly ... 45
gage heights ... 44
rating table ... 45
Maxwell ditch at—
Echo, Oreg.:
description ... 197
discharge ... 197
discharge of wasteway of ... 197
Mehama, Oreg.,
North Fork of Santiam River near:
description ... 224-225
discharge ... 225
gage heights ... 225
Methods of computing stream flow ... 10-11
Methods of measuring stream flow ... 6-10
Methow River near—
Pateros, Wash.:
description ... 35
discharge ... 35
discharge, monthly ... 37
gage heights ... 36
rating table ... 36
Methow River basin:
description ... 34
Milton, Oreg.,
Walla Walla River at and near:
description ... 178, 179-180
discharge ... 178, 180
discharge, monthly ... 179, 181
gage heights ... 179, 180-181
rating table ... 179
Walla Walla River, South Fork, near:
description ... 176
discharge ... 177
discharge, monthly ... 178
gage heights ... 177
rating table ... 178
Minam River near—
Elgin, Oreg.:
discharge ... 229
Miner's inch, definition of ... 3
Minidoka, Idaho,
Snake River near:
description ... 93-94
discharge ... 94, 96
discharge, monthly ... 95
gage heights ... 94-95
rating table ... 95
Missoula River at—
Missoula, Mont.:
description ... 16
discharge ... 17
discharge, monthly ... 18
gage heights ... 17
rating table ... 18


Digitized by Google

Page.

Molalla River at—
Dickey Prairie, Oreg.:
description ..... 227
discharge ..... 227
gage heights ..... 227
Montgomery Ferry, Idaho,
Snake River near:
*See* Snake River near Minidoka.
Moran, Wyo.,
South Fork of Snake River near:
description ..... 101
discharge ..... 102
discharge, monthly ..... 103
gage heights ..... 102
rating table ..... 103
Morrisey canal near—
North Yakima, Wash.:
discharge ..... 77
head works location ..... 54
Moxee canal near—
North Yakima, Wash.:
discharge ..... 58
gage heights ..... 58
head works location ..... 53, 58
Multiple-point method of measuring discharge, description of ..... 9
Naches-Cowiche canal near—
North Yakima, Wash.:
description ..... 73
discharge ..... 73
gage heights ..... 73
head works location ..... 54, 73
Naches River, Wash.:
canals taking water from:
list of ..... 54
station data ..... 65–77
description ..... 43
near mouth of Tieton River (below):
description ..... 84–85
discharge ..... 85
discharge, monthly ..... 86
gage heights ..... 85
rating table ..... 85
near Nile:
description ..... 82–83
discharge ..... 83
discharge, monthly ..... 84
gage heights ..... 83–84
rating table ..... 84
near North Yakima:
description ..... 86–87
discharge ..... 87
discharge, monthly ..... 88
gage heights ..... 87–88
rating table ..... 88
Nelson canal near—
North Yakima, Wash.:
discharge ..... 77
head works location ..... 54
Nevada ditch—
below Vale, Oreg.:
description ..... 136
discharge ..... 136–137
wasteways of:
discharge ..... 137

Page.

Nile, Wash.
Naches River near:
description ..... 82–83
discharge ..... 83
discharge, monthly ..... 84
gage heights ..... 83–84
rating table ..... 84
Nolin, Oreg.,
Slusher & Gould ditch near:
description ..... 191
discharge ..... 191
North Yakima, Wash.,
Broadguage canal near:
description ..... 73
discharge ..... 73
gage heights ..... 73
head works location ..... 54
Clark canal near:
description ..... 68
discharge ..... 68
gage heights ..... 68
head works location ..... 54, 68
Cox canal near:
discharge ..... 77
head works location ..... 54
Fortune canal near:
description ..... 67
discharge ..... 67
gage heights ..... 67
head works location ..... 54, 67
Fowler canal near:
discharge ..... 59
gage heights ..... 60
head works location ..... 53, 59
Gleed canal near:
description ..... 69
discharge ..... 69
gage heights ..... 70
head works location ..... 54, 69
Granger canal near:
discharge ..... 77
head works location ..... 53
Hubbard canal near:
discharge ..... 59
gage heights ..... 59
head works location ..... 53, 59
Kelly canal near:
discharge ..... 77
head works location ..... 54
Laswell canal near:
discharge ..... 77
head works location ..... 54
Lower Scott canal near:
description ..... 67
discharge ..... 67
gage heights ..... 68
head works location ..... 54, 67
Lowry canal near:
description ..... 68
discharge ..... 69
gage heights ..... 69
head works location ..... 54, 68
McCormick canal near:
description ..... 72


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North Yakima, Wash.—Continued. Page.
McCormick canal near:
discharge 72
gage heights 72
head works location 54, 72
Morrisey canal near:
discharge 77
head works location 54
Moxee canal near:
discharge 58
gage heights 58
head works location 53, 58
Naches-Cowiche canal near:
description 73
discharge 73
gage heights 73
head works location 54, 73
Naches River near:
description 86–87
discharge 87
discharge, monthly 88
gage heights 87–88
rating table 88
Nelson canal near:
discharge 77
head works location 54
Power canal at:
description 74
discharge 74
gage heights 75
head works location 54, 74
Prosser power flume near—
Prosser, Wash.:
discharge 78
R. S. & C. Co.'s canal near:
discharge 77
Selah-Moxee canal near:
discharge 57
gage heights 57
head works location 53, 57
Selah Valley canal near:
description 65
discharge 65
gage heights 65
head works location 54, 65
Shanno canal at:
description 75
discharge 75
gage heights 75–76
head works location 54, 74
Shanno-Fruitvale canal near:
discharge 78
head works location 54
Taylor canal near:
discharge 57
gage heights 58
head works location 53, 57
Tieton River near:
description 89
discharge 89
discharge, monthly 90
gage heights 89–90
rating table 90
Town canal near:
description 76
discharge 77

North Yakima, Wash.—Continued. Page.
Town canal near:
gage heights 77
head works location 54, 76
Union canal near:
description 76
discharge 76, 77
gage heights 76
head works location 54
Upper Scott canal near:
discharge 77
head works location 54
Wapatox canal near:
description 66
discharge 66
gage heights 66
head works location 54, 66
White & Leach canal near:
description 71
discharge 71
gage heights 72
head works location 54, 71
Yakima River near:
description 45
gage heights 46
Yakima Valley canal near:
description 76
discharge 77
gage heights 71
head works location 54, 76
Norwood ditch—
above Vale, Oreg.:
discharge 147
Ochoco River near—
Prineville, Oreg.:
discharge 229
Odell, Oreg.,
East Fork of Deschutes River at:
description 210
discharge 210
discharge, monthly 211
gage heights 210–211
rating table 211
Odell Lake outlet, Oreg.:
discharge 229
Okanogan River basin:
description 31
Olsen canal near—
Ellensburg, Wash.:
discharge 56
gage heights 56
head works location 53, 56
Ontario, Oreg.,
Brosnan ditch near:
discharge 137
Malheur River near:
description 131
discharge 132
discharge, monthly 133
gage heights 132
rating table 133
wasteways near:
discharge 121, 137
Wilson ditch near:
description 121
discharge 121


Digitized by Google

Ora, Idaho, Page.
North fork of Snake River near:
description 91-92
discharge 92
discharge, monthly 93
gage heights 92
rating table 93
Oregon Land and Water Company's ditch at—
Umatilla, Oreg.:
description 199
discharge 199
discharge, monthly 201
gage heights 200
rating table 200
Owyhee, Oreg.,
Cow Hollow wasteway near:
discharge 120
Fletcher wasteway near:
discharge 120
Owyhee ditch near:
description 118
discharge 119
discharge, monthly 120
gage heights 119
rating table 120
Owyhee River near:
description 116
discharge 117
discharge, monthly 118
gage heights 117
rating table 118
Owyhee ditch near—
Owyhee, Oreg.:
description 118
discharge 119
discharge, monthly 120
gage heights 119
rating table 120
Owyhee ditch wasteways:
discharge 120-121
Owyhee River, Oreg.:
description 91
near Owyhee:
description 116
discharge 117, 229
discharge, monthly 118
gage heights 117
rating table 118
Owyhee River Valley,
ditches in:
station data 118-121
Palouse River, Wash.:
description 91
near Elberton:
description 169-170
discharge 170
gage heights 170
near Hooper:
description 171
discharge 171
discharge, monthly 173
gage heights 172
rating table 172
Pasco, Wash. Page.
Columbia River near:
description 13-14
gage heights 14
Pateros, Wash.,
Methow River near:
description 35
discharge 35
discharge, monthly 37
gage heights 36
rating table 36
Pauline Creek near—
Rosland, Oreg.:
discharge 229
Pendleton, Oreg.
Birch Creek near:
discharge 228
Farmers' mill ditch at:
description 190
discharge 190
gage heights 190
McKay Creek near:
discharge 229
Umatilla River near:
description 184
discharge 185
gage heights 185
Wild Horse Creek near:
discharge 230
Pend Oreille River. (*See* Clark Fork.)
Peterson and Teter ditch above—
Vale, Oreg.:
discharge 147
Pilot Butte Canal near—
Bend, Oreg.:
description 217
discharge 217
discharge, monthl 219
gage heights 218
rating table 218
Pioneer ditch at—
Echo, Oreg.:
description 196
discharge 196
Powder River near—
Baker City, Oreg.:
description 148
discharge 149
discharge, monthly 150
gage heights 149
rating table 150
Power Canal at—
North Yakima, Wash.:
description 74
discharge 74
gage heights 75
head works location 54, 74
Presto, Idaho,
Blackfoot River near:
description 106
discharge 106
discharge, monthly 107-108
gage heights 106-107
rating table 107


Digitized by Google

Priest River, Idaho. Page.
Clark Fork of the Columbia at:
description 15
discharge 15
discharge, monthly 16
gage heights 15
rating table 16
Priest River at (below):
Priest River at—
Priest River, Idaho:
description 23-24
discharge 24
gage heights 24
Prineville, Oreg.,
Carmichael ditch at:
discharge 219
Crooked River near:
discharge 220
Ochoco River near:
discharge 229
Prosser, Wash.,
Prosser power flume near:
discharge 78
Taylor power flume near:
description 78
Yakima River near:
description 48
discharge 48
gage heights 49
Prosser power flume near—
Prosser, Wash.:
discharge 78
Quigley Creek near
Halley, Oreg.:
discharge 229
Rating curves, methods of construction of.. 10-11
Rating tables, methods of construction of.. 10, 11
Ravensdale, Wash.,
Cedar River near:
description 230-231
gage heights 231
Rock Creek near—
Arlington, Oreg.:
description 206
discharge 206
discharge, monthly 207
gage heights 206-207
rating table 207
Rock Creek near—
St. John, Wash.:
description 173
discharge 173
discharge, monthly 175
gage heights 174
rating table 174
Rosland, Oreg.,
Findley's ditch near:
discharge 216
Pauline Creek near:
discharge 229
Roslyn, Wash.,
Clealum River near:
description 80-81
discharge 81
discharge, monthly 82
gage heights 81
rating table 82

Page.
R. S. & C. Co.'s canal near—
North Yakima, Wash.:
discharge 77
Rules for computation, fundamental and special 4-8
Run-off in inches, definition of 4
St. Anthony, Idaho,
Teton River near:
description 99
discharge 100
discharge, monthly 101
gage heights 100
rating table 101
St. John, Wash.,
Rock Creek near:
description 173
discharge 173
discharge, monthly 175
gage heights 174
rating table 174
Salmon Creek near—
Malott, Wash.:
description 32-33
discharge 33
discharge, monthly 34
gage heights 33
rating table 34
Salmon River post-office, Oreg.,
Sandy River near:
discharge 229
Sand Hollow ditch above—
Vale, Oreg.:
description 136
discharge 136
Sandy River near—
Salmon River post-office, Oreg.:
discharge 229
Santiam River at—
Jefferson, Oreg.:
description 224
discharge 224
gage heights 224
Santiam River, North Fork, near—
Mehama, Oreg.:
description 224-225
discharge 225
gage heights 225
Santiam River, South Fork, at—
Waterloo, Oreg.:
description 225
discharge 226
gage heights 226
Satas River near—
Alfalfa, Oreg.:
discharge 229
Scott ditch above Vale, Oreg.:
discharge 148
Second-feet per square mile, definition of... 4
Second-foot, definition of 3
Selah-Moxee canal near—
North Yakima, Wash.:
discharge 57
gage heights 57
head works location 53, 57


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elah Valley canal near— Page.
North Yakima, Wash.:
description 65
discharge 65
gage heights 66
head works location 54,65
Shanno canal at—
North Yakima, Wash.:
description 75
discharge 75
gage heights 75-76
head works location 54,75
Shanno-Fruitvale canal near—
North Yakima, Wash.:
discharge 78
head works location 54
Sheiman's ranch, near Asotin Wash.,
Asotin Creek at:
description 168
gage heights 169
Sheridan, Oreg.,
Yamhill River near:
discharge 230
Shoshone, Idaho,
Big Wood River near:
description 113
gage heights 113
Shoshone Falls, Idaho,
Snake River between Twin Falls and:
discharge 96
Silver Creek near—
Thompsons Valley, Oreg.:
discharge 229
Silver Lake ditch near—
Joseph, Oreg.:
description 163
discharge 163
gage heights 164
Single-point method of measuring discharge,
description of 9
Sinlahekin Creek near—
Loomis, Wash.:
description 31-32
gage heights 32
Sisters, Oreg.,
Squaw Creek near, above diversions:
discharge 229
Skykomish River, South Fork, near—
Index, Wash.:
description 232
gage heights 232 233
Slusher & Gould ditch near—
Nolin, Oreg.:
description 191
discharge 191
Slope method of measuring discharge, use
and value of 6
Snake River, Idaho:
near American Falls (above):
description 91
discharge 96
near Minidoka (Montgomery Ferry):
description 93 94
discharge 94,96
discharge, monthly 95
gage heights 94-95
rating table 95
Snake River, Idaho: Page.
near Shoshone Falls, between Twin
Falls and:
discharge 96
seepage and waste measurements 96
Snake River basin;
description 91
Snake River, North Fork, near—
Ora, Idaho:
description 91-92
discharge 92
discharge, monthly 93
gage heights 92
rating table 93
Snake River, South Fork, near—
Lyon, Idaho:
description 103-104
discharge 104
discharge, monthly 105
gage heights 104-105
rating table 105
Moran, Wyo.:
description 101
discharge 102
discharge, monthly 103
gage heights 102
rating table 103
Snohomish River basin:
description 232
Snoqualmie River near—
Snoqualmie Falls, Wash.:
description 233
gage heights 234
Spokane, Wash.,
Little Spokane River near:
description 31
gage heights 31
Spokan River at—
Spokane, Wash.:
description 25-26
discharge 26
discharge, monthly 27
gage heights 26
rating table 27
Spokane River basin:
description 24
Squaw Creek near—
Sisters, Oreg., above diversions:
discharge 229
Stream flow:
field methods of measuring 6-10
office methods of computing 10-11
Succor Creek near—
Homedale, Idaho:
description 114-115
discharge 115
discharge, monthly 116
gage heights 115
Sunnyside canal near—
Yakima, Wash.:
description 61
discharge 61
gage heights 62
head works location 53,61


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Suver, Oreg., Page.
Luckiamute River near:
description 226
discharge 226
gage heights 227
Tables, explanation of 4
Taylor canal near—
North Yakima, Wash.:
discharge 57
gage heights 58
head works location 53, 57
Taylor power flume near—
Prosser, Wash.:
discharge 78
Tekoa, Wash.,
Hangman Creek at and near:
description 27-28, 29
discharge, daily 29
gage heights 28
North Fork of Hangman Creek near:
description 29-30
discharge 30
gage heights 30
Teton River near—
St. Anthony, Idaho:
description 99
discharge 100
discharge, monthly 101
gage heights 100
rating table 101
Thompsons Valley, Oreg.,
Silver Creek near:
discharge 229
Thorp, Wash.,
Cascade canal near:
discharge 54
gage heights 55
head works location 53, 54
West Kittitas canal near:
discharge 55
gage heights 55
head works location 53, 55
Tieton River near—
North Yakima, Wash.:
description 89
discharge 89
discharge, monthly 90
gage heights 89-90
rating table 90
Town canal near—
Ellensburg, Wash.:
discharge 56
gage heights 56
head works location 53, 55
North Yakima, Wash.:
description 76
discharge 77
gage heights 77
head works location 54, 76
Tumallo Creek near—
Bend, Oreg.:
discharge 230
Turner ditch—
above Vale, Oreg.:
discharge 148
Twin Falls, Idaho— Page.
Snake River between Shoshone Falls and:
discharge 96
Twin Falls canal, Idaho:
discharge 96
water diverted by 96
Umatilla, Oreg.,
Bowman ditch at:
description 201
discharge 201
Brownell ditch at:
description 201
discharge 201
Oregon Land and Water Company's ditch at:
description 199
discharge 199
discharge, monthly 201
gage heights 200
rating table 200
Umatilla River near. *See* Umatilla River.
Umatilla River Basin:
description 181
Umatilla River near—
Echo, Oreg.:
discharge 230
Fosters, Oreg.:
discharge 230
Gibbon, Oreg.:
description 181-182
discharge 182
discharge, monthly 183
gage heights 182-183
rating table 183
Pendleton, Oreg.:
description 184
discharge 185
gage heights 185
Umatilla, Oreg.:
description 186
discharge 186
discharge, monthly 190
gage heights 189
rating table 189
Yoakum, Oreg.:
description 185-186
discharge 186
discharge, monthly 187
gage heights 186-187
rating table 187
Umatilla River basin:
description 181
ditches in:
station data 190-210
springs in:
discharge 201
Union canal at—
North Yakima, Wash.:
description 76
discharge 76, 78
gage heights 76
head works location 54-76
Upper Scott canal near—
North Yakima, Wash.:
discharge 77
head works location 54


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Vale, Oreg., Page.
Bully Creek at and above:
description 137-138, 140
discharge 138, 140
discharge, monthly 139
gage heights 138-139, 141
rating table 139
ditches in Malheur River Valley above:
descriptions and discharges 133-136
ditches in Willow Creek Valley above:
discharge 146-148
McGregor wasteway below:
discharge 137
Malheur River near:
description 126, 129
discharge 127, 129
discharge, daily 128
discharge, monthly 129, 131
gage heights 127-123, 130
rating table 130
Nevada ditch below:
discharge 136-137
Velocity methods of measuring discharge, description of 7-10
Vertical velocity-curve method of measuring discharge, description of 9
Vines ditch above—
Vale, Oreg.:
description 133
discharge 133
Walla Walla River at and near—
Milton, Oreg.:
description 178, 179-180
discharge 178, 180
discharge, monthly 179, 181
gage heights 179, 180-181
rating table 179
Walla Walla River, South Fork, near—
Milton, Oreg.:
description 176
discharge 177
discharge, monthly 178
gage heights 177
rating table 178
Walla Walla River basin:
description 176
Wallowa, Oreg.,
Bear Creek near:
discharge 228
Company ditch near:
description 166
discharge 166
discharge, monthly 167
gage heights 166-167
Wallowa River near. *See* Wallowa River.
Wallowa Lake near--
Joseph, Oreg.:
description 156
discharge 156
Wallowa River near—
Elgin, Oreg.:
description 161-162
discharge 162
discharge, monthly 163
gage heights 162
rating table 163
Wallowa River near— Page.
Joseph, Oreg.:
description 156-157
discharge 157
discharge, monthly 159
gage heights 157-158
rating table 158
Wallowa, Oreg.:
description 159
discharge 160
discharge, monthly 161
gage heights 160
rating table 161
Wallowa Falls, above Wallowa Lake, Oreg.:
discharge 230
Wallowa River Valley,
ditches in:
descriptions and discharges 163-167
Wapatox canal near—
North Yakima, Wash.:
description 66
discharge 66
gage heights 66
head works location 54, 66
Waterloo, Oreg.,
South Fork of Santiam River at:
description 225
discharge 226
gage heights 226
Weir method of measuring discharge, requirements of 7
Wenache River at—
Cashmere, Wash.:
description 40
discharge 41
discharge, monthly 42
gage heights 41
rating table 42
Wenache River basin:
description 40
Westfall, Oreg.,
Malheur River near:
description 124
discharge 124
discharge, monthly 126
gage heights 125
rating table 125
West Kittitas canal near—
Thorp, Wash.:
discharge 55
gage heights 55
head works location 53, 55
White & Leach canal near—
North Yakima, Wash.:
description 71
discharge 71
gage heights 72
head works location 54, 71
White River basin:
description 230
Wild Horse Creek near—
Pendleton, Oreg.:
discharge 230



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Willamette River at— Page.
Albany, Oreg.:
description 223
discharge 223
gage heights 223
Willamette River, Coast Fork, near—
Goshen, Oreg.:
description 221
discharge 221
gage heights 222
Willamette River, Middle Fork, at—
Jasper, Oreg.:
description 220
discharge 221
gage heights 221
Willamette River basin:
description 220
Willow Creek basin:
description 202
Willow Creek [of the Columbia] near—
Arlington, Oreg.:
description 202
discharge 202
discharge, monthly 203
gage heights 202
rating table 203
Willow Creek [of the Malheur] near—
Dell, Oreg.:
description 143–144
discharge 144
discharge, monthly 146
gage heights 144–145
rating table 145
Malheur, Oreg.:
description 141
discharge 142
discharge, monthly 143
gage heights 142
rating table 143
Willow Creek Valley—
ditches in, above Vale, Oreg.:
discharge 145–148
Wilson & Co.'s ditch at—
Echo, Oreg.:
description 194
discharge 194
Wilson ditch near—
Ontario, Oreg.:
description 121
discharge 121
Winans City, Oreg.,
Hood River at:
description 219–220
discharge 220
gage heights 220
Yakima, Wash.,
Sunnyside canal near:
description 61
discharge 61
gage heights 62
head works location 53, 61
Wide Hollow waste near:
discharge 78
Yakima River near. *See* Yakima River.
Yakima River Basin: Page.
description 43
Yakima Indian Reservation, Wash.,
New Reservation canal in:
discharge 60
gage heights 60
head works location 53, 60
Old Reservation canal in:
discharge 61
gage heights 61
head works location 53, 61
Yakima River, Wash.:
canals taking water from:
list of 53
station data 54–64
near Kiona:
description 49–50
discharge 50
discharge, monthly 52
gage heights 51
rating table 51
near Martin:
description 43–44
discharge 44
discharge, monthly 45
gage heights 44
rating table 45
near North Yakima:
description 45
gage heights 46
near Prosser:
description 48
discharge 48
gage heights 49
near Yakima:
description 46
discharge 47
gage heights 47
Yakima Valley
canals in:
description 52–53
list of 53–54
station data 54–78
Yakima Valley canal near—
North Yakima, Wash.:
description 70
discharge 71
gage heights 71
head works location 54, 70
Yamhill River near—
Sheridan, Oreg.:
discharge 220
Yoakum, Oreg.,
Horseshoe Irrigation Company's ditch at:
description 194
Umatilla River near:
description 185–186
discharge 186
discharge, monthly 187
gage heights 186–187
rating table 187
Zindel, Wash.,
Grande Ronde River, at:
description 155
gage heights 155–158


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# CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 178.]

The publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

Most of the above publications may be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they may be obtained, free of charge (except classes 2, 7, and 8), on application.

2. A certain number are delivered to Senators and Representatives in Congress, for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they may be had at practically cost.

4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they may be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports.

*Series P.*—The hydrographic progress reports contain the results of stream measurements. A report is issued for every calendar year, containing the results of data collected during that year. These reports were first published as a part of the Director's annual report or as a bulletin; they are now published as water-supply and irrigation papers. The following is a list, by years, of the publications containing the progress reports of stream measurements. A detailed index of these reports (1888–1903) is published as Water-Supply Paper No. 119.

1888. Tenth Annual Report, Part II.
1889. Eleventh Annual Report, Part II.
1890. Twelfth Annual Report, Part II.
1891. Thirteenth Annual Report, Part III.
1892. Fourteenth Annual Report, Part II.
1893. Bulletin No. 131.
1894. Bulletin No. 131; Sixteenth Annual Report, Part II.
1895. Bulletin No. 140.
1896. Water-Supply Paper No. 11; Eighteenth Annual Report, Part IV.
1897. Water-Supply Papers Nos. 15 and 16; Nineteenth Annual Report, Part IV.
1898. Water-Supply Papers Nos. 27 and 28; Twentieth Annual Report, Part IV.
1899. Water-Supply Papers Nos. 35, 36, 37, 38, and 39; Twenty-first Annual Report, Part IV.
1900. Water-Supply Papers Nos. 47, 48, 49, 50, 51, and 52; Twenty-second Annual Report, Part IV.
1901. East of Mississippi River, Water-Supply Papers Nos. 65 and 75.
West of Mississippi River, Water-Supply Papers Nos. 66 and 75.



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1902. East of Mississippi River, Water-Supply Papers Nos. 82 and 83.
West of Mississippi River, Water-Supply Papers Nos. 84 and 85.
1903. East of Mississippi River, Water-Supply Papers Nos. 97 and 98.
West of Mississippi River, Water-Supply Papers Nos. 99 and 100.
1904. East of Mississippi River, Water-Supply Papers, Nos. 124, 125, 126, 127, 128, and 129.
West of Mississippi River, Water-Supply Papers Nos. 130, 131, 132, 133, 134, and 135.
1905. East of Mississippi River, Nos. 165, 166, 167, 168, 169, 170, and 171.
West of Mississippi River, Nos. 171, 172, 173, 174, 175, 176, 177, and 178.

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Correspondence should be addressed to

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UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

JULY, 1906.

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UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

# PREVENTION OF STREAM POLLUTION BY DISTILLERY REFUSE

## BASED ON INVESTIGATIONS AT LYNCHBURG, OHIO

BY

HERMAN STABLER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1906

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# CONTENTS.


| | Page. |
|---|---|
| Scope of investigation | 5 |
| Acknowledgments | 5 |
| Distillery processes and sources of pollution | 5 |
| Grain distillation | 5 |
| Treatment of slop | 8 |
| Sources and character of pollution | 9 |
| Effect of polluting effluents on the stream | 12 |
| Disposal of distillery effluent without stream pollution | 16 |
| Filtration | 16 |
| Precipitation | 17 |
| Fermentation | 18 |
| Evaporation | 18 |
| Amount of slops and recoverable solid matter | 18 |
| Method of evaporation | 21 |
| Cost of plant | 26 |
| Cost of process | 28 |
| Value of products | 28 |
| Profits | 30 |
| Result at Lynchburg distillery | 31 |
| Summary | 34 |


# ILLUSTRATIONS.


| | Page. |
|---|---|
| PLATE I. Smith-Vaile filter press | 22 |
| FIG. 1. Vacuum mash cooker | 6 |
| 2. Continuous beer still | 7 |
| 3. Yaryan's triple-effect evaporator | 23 |
| 4. American process dryer | 25 |
| 5. Hoffman-Ahlers triple-effect vacuum evaporator | 32 |




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# PREVENTION OF STREAM POLLUTION BY DISTILLERY REFUSE.

By HERMAN STABLER.

## SCOPE OF INVESTIGATION.

This report gives an account of investigations carried on near Lynchburg, Ohio, to discover feasible means of preventing the pollution of streams by distillery refuse. Lynchburg is in Highland County, Ohio, a few hundred yards east of the East Branch of Little Miami River and about 60 miles northeast of Cincinnati. It has a population of a little less than 1,000. Above and below Lynchburg the East Branch of Little Miami River flows through an agricultural district, and as the town has no sewerage system the stream is not seriously polluted except by the distillery refuse. The investigation was therefore confined to the following subjects: (1) The processes at the distillery and the sources of pollution; (2) the effect of the pollution on the stream; (3) the economical disposal of distillery wastes in such way that there will be no pollution of streams.

## ACKNOWLEDGMENTS.

This work was done under the cooperative agreement between the United States Geological Survey and the Ohio State board of health.[a]

All laboratory work, both chemical and bacteriological, on the analyses in table 1 (6 samples from East Branch of Little Miami River) was performed by officials of the Ohio State board of health under the direction of Dr. E. G. Horton, bacteriologist and chemist. All laboratory work by the writer was done in the laboratory of the Ohio State board of health. The investigation was directed by Mr. M. O. Leighton, chief of the division of hydro-economics, United States Geological Survey, to whom is due in very great measure the value of the results obtained. The investigation received the hearty support of Messrs. Freiburg and Workum, owners of the distillery, through their superintendent, W. M. Cleveland, and his principal assistant and chemist, G. L. Bering. Much of the value of the examination is due to the special facilities for work and information offered by these gentlemen at no little inconvenience to themselves.

The courtesy of the Hoffman-Ahlers Company, of Cincinnati, Ohio; the Platt Iron Works, of Dayton, Ohio, and the Yaryan Company and American Process Company, of New York City, in furnishing illustrations to accompany this report, is also acknowledged with thanks.

## DISTILLERY PROCESSES AND SOURCES OF POLLUTION.

### GRAIN DISTILLATION.

The distillery at Lynchburg manufactures grain liquors, including principally rye and bourbon whisky. The process of manufacture in such an establishment is generally about as follows: The grain, freed from husks or chaff and other impurities, is ground to a coarse

[a] Twenty-sixth Ann. Rept. U. S. Geol. Survey, 1905, pp. 215-217.



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meal in roller mills, the fineness of grinding being varied somewhat with the grade of spirits to be produced.

Definite amounts of the meal are weighed out for "mashing" by Government internal-revenue officers and conveyed to cookers. The cooker is a closed iron digester, cylindrical in shape, horizontally placed, and provided with stirring apparatus.

The Hoffman-Ahlers vacuum mash cooker is illustrated by fig. 1. In operation with corn the cooker is about half filled with water (20 gallons of water being used for each bushel of grain to be mashed) and the stirring apparatus, seen within the shell of the cooker on the left and actuated by the belt pulley at the end of the machine, is started. Steam is then admitted, and the grain meal is introduced through the manhole on top. The manhole is then closed and steam forced in until a pressure of about 55 pounds per square inch is reached. To accomplish a thorough digestion, this pressure is maintained about half an hour after the steam is shut off. A vacuum pump connecting at the bell on top of the machine is then started and by reduction in pressure the contents of the cooker are cooled down to about 63° C. Ground barley malt mixed with a little water is then added and thoroughly mixed with the contents of the cooker for about half an hour. During this time the diastase of the malt acts upon the starch in the digested grain meal and converts it into maltose and dextrinous matter, the object of the distiller being to increase the maltose and decrease the dextrinous product.

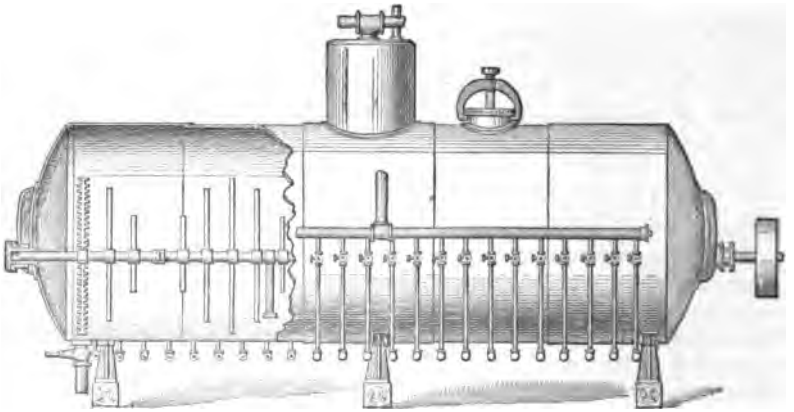

FIG. 1.—Vacuum mash cooker.

The distiller desires to produce from his grain the greatest possible amount of alcohol, and therefore fixes the narrow limit of 60° to 63° for mashing. A higher temperature would favor the production of a greater quantity of compounds not readily convertible into ethyl alcohol. In addition to the temperature, the quality of the malt and of the water has a considerable effect upon mashing. Distiller's malt is now generally specially prepared to produce a rapid and thorough conversion of starch, the germ of the malted grain being highly developed to produce a maximum diastatic power. The water used may retard or accelerate the action of diastase. Generally speaking, absence of organic matter or putrefactive products thereof and the presence of calcium sulphate are favorable to rapid conversion of starch.

After cooling the wort is conveyed from the cooker to the fermenting vats. These vats are large, open wooden tubs, cylindrical in shape and vertically placed. The wort is diluted to a desired consistency and there is then added to it a yeast mash, which produces a fermentation by which the maltose is broken up and forms, chiefly, alcohol and carbon dioxide. All the maltose having been disposed of, the residuum of diastase in the wort attacks the dextrinous matter, producing more maltose, which in turn is fermented. As in the previous processes, the production of a maximum amount of alcohol is kept to the fore. The yeast

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used is prepared from pure cultures to avoid loss of alcohol by the action of wild yeasts producing acetic, lactic, or other acids. The temperature is not made any higher than the point at which a healthy fermentation can be started, in order to avoid the production of an excess of aldehyde and fusel oil (the chief impurities in the manufacture of alcohol) and the loss of alcohol by evaporation. The maximum time allowed by law for fermentation is seventy-two hours. The distiller therefore uses an active top fermentation, by which all sugar is converted into alcohol as rapidly and as completely as possible. Carbon dioxide bubbles up from the surface of the liquid in the tubs in great quantity soon after fermentation is started, and a top coating, composed of the suspended matter in the wort, rapidly

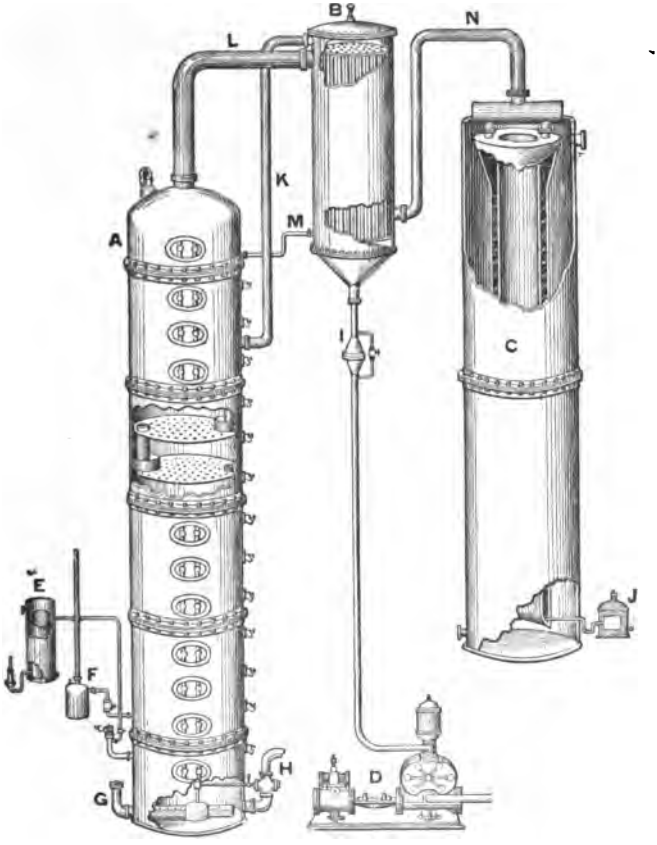


FIG. 2.—Continuous beer still.

forms to a thickness of several inches. As the fermentation nears completion the gas escapes in diminishing quantity and the top coating of suspended matter gradually subsides, leaving a light yellow liquor—a slimy mixture of solid matter, water, alcohol, fusel oil, aldehyde, acids, etc.—known technically as beer.

The beer contains a small percentage of alcohol, which is separated from the other products by distillation. This separation is now generally accomplished by means of a continuous distilling apparatus, modeled more or less upon the plan of the Coffey still. Such a still is shown in fig. 2. The pump *D* forces the beer through the check valve *I* into the tubular heater and condenser *B*. In passing through the tubes of *B* the beer is heated by the vapor which surrounds them and then passes into the still *A* through the pipe *K*. On entering

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the still the beer starts on a downward course, but is met by an upward rush of steam introduced through the perforated pipe *G*.

The still is fitted with an ingenious arrangement of perforated plates having tubular overflows (shown near the center of the illustration), which brings each particle of beer into contact with the ascending steam. Since alcohol is vaporized at a much lower temperature than water, the steam pressure (and consequently the temperature) is so regulated with observation of the steam gage *F* as to effect a complete vaporization of the alcohol, which, together with some water vapor, passes off through *L* into the tube chamber of *B*. Here the alcoholic vapor surrounding the tubes is cooled by the beer within them and some impurities are condensed and returned to the still through *M*. The purer product, however, escapes through *N* to the condenser and cooler *C*. As may be seen in the illustration, the alcoholic vapor takes a spiral course between two bodies of water, which cool and condense it until it emerges in the try box *J* as a mixture of alcohol and water, or raw spirits. The try box is locked and sealed by an internal-revenue officer, and the degree of concentration of the spirits may be read from a hydrometer floating in the liquor. It may be here mentioned that the distiller has no access to the spirituous liquor after it leaves the still, all subsequent operations being under the supervision of internal-revenue officers, who lock and seal all means of access until the liquor is barreled, gaged, and stored in a warehouse, from which it can be legally removed only by payment of the revenue tax.

The spirit product of the still accounts, of course, for only a small portion of the beer. The dealcoholized liquid, known as slop, gravitates to the bottom of the still and is blown out at *H*. At *E* is a contrivance, known as the slop tester, used in determining the efficiency of the still. The slop is variously wasted, pumped back for further use, fed to cattle, or treated for recovery of a dried stock food. It forms the great body of liquid waste from a distillery.

The crude spirit as it comes from the still contains aldehyde and fusel oil, which give it a nauseating odor and taste. These are partially removed by filtration through wood charcoal. The spirit is further purified by a second distillation in a rectifier. This is an intermittent process, the spirit being introduced by charges. The first vapor is chiefly aldehyde and fusel oil and is collected and sold as such. Of the remainder a part may be sold as alcohol or the whole may be reduced to a suitable proof and stored in oak barrels for the production of whisky by aging. During the aging process, which generally lasts from two to eight years, the residuum of fusel oil is broken up and the liquor acquires the characteristic aroma and taste of commercial whisky. Coloring matter is absorbed from the barrels by the spirit, which changes from colorless to whisky brown.

From the rectifier a small amount of waste slop and wash water passes off. This is dilute, and not usually sufficient in quantity to produce a nuisance. It will be hereinafter referred to as waste A. At Lynchburg this waste water was run directly into the stream. Its quantity was so small and its flow so irregular, as compared with the other wastes, that it received no detailed consideration in the investigation.

## TREATMENT OF SLOP.

In the distillery at Lynchburg, as in many other distilleries, a portion of the slop from the still was used again as a diluent in the fermenting vats; the greater part of the suspended matter was screened out, dried, and sold as stock food; a portion of the remainder was fed to cattle; the rest was wasted. A detailed description of the treatment is given in order to furnish a complete understanding of the proposed method of slop disposal. This description may be considered as characteristic, though details vary somewhat in the practice of different distilleries.

For clearness and convenience the slops from corn and rye distillation, respectively, will be denominated "corn" and "rye" slops. As the treatment of the liquor is described, the various slops will be further designated by numbers and letters.

The slop as it comes from the still will be referred to as "slop rye 1" and "slop corn 1."

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Slop rye 1 flows by gravity through a flume and pipe line to a receiving well at a building known as the "slop house;" thence it is pumped to a perforated brass sheet or screen, which is set at such an inclination that the greater part of the slop passes through and is carried away in a wooden flume to settling vats. This thin slop from the screen will be designated "slop rye 2." The coarser suspended matter, with some thin liquor, passes over the screen and falls into a wooden tub. This is slop rye 3.

Slop rye 2 is allowed to stand in settling vats for a few hours, when the supernatant, slop rye 4, is allowed to run into a pool of accumulated slops and filth. The heavier liquor from the vat bottoms, slop rye 5, is drawn off and fed to cattle, hundreds of which are kept for the sole purpose of disposing of this slop.

Slop rye 3 is forced into filter presses, which give a product of a thin liquor, slop rye 6, and damp feed, rye 7. The feed, containing about 60 per cent of moisture, is passed through a revolving horizontal cylindrical hot-air dryer, which reduces the moisture to less than 10 per cent. It is then sacked and sold as a concentrated cattle feed. Slop rye 6 joins slop rye 4 in the pool mentioned above.

Slop corn 1 flows over a preliminary screen set in the flume bottom, and is thereby separated into a thin slop, corn 1a, and a thicker slop, corn 1b. Slop corn 1a is pumped back to the fermenting vats, where it is used to dilute the wort from the cookers. Slop corn 1b follows the same course as slop rye 1, and is divided in exactly the same manner. The only variation in the treatment of the two is that slop corn 6, instead of passing to the pool, is pumped back to join slop corn 1a.

To recapitulate, the products are as follows:

1. Slops from still, rye 1 and corn 1.
2. Slops from preliminary screen for corn, corn 1a and corn 1b.
3. Slops passing to main screen, rye 1 and corn 1b.
4. Thin slops from screen passing to settling vats, rye 2 and corn 2.
5. Thick slops from screen passing to filter presses, rye 3 and corn 3.
6. Thin slops from settling vats discharged into pool, rye 4 and corn 4.
7. Thick slop from settling vats, fed to cattle, rye 5 and corn 5.
8. Thin slops from filter presses, rye 6 and corn 6.
9. Feed grains from filter presses, rye 7 and corn 7, to be dried.
10. Dried cattle food, rye 8 and corn 8, to be sacked and sold.

The cattle to which slops rye 5 and corn 5 are fed, and which subsist largely on this liquid food, produce quantities of semiliquid manure. A portion of this is hauled away to be used as compost on adjacent farms. The remainder, with all the more dilute wash water from the cleansing of the cattle pens, joins slops rye 4, rye 6, and corn 4 in an open barnyard pool, forming the chief liquid waste from the distillery. This pool drains, by a continuous stream and by large charges, into the creek, and will be referred to as waste B.

## SOURCES AND CHARACTER OF POLLUTION.

It will be observed that there were two sources of pollution—waste A, a thin slop liquor of milky appearance, and waste B, a thin slop liquor mixed with filth from cattle stables. From 10,000 to 15,000 gallons were discharged each day, bearing into the stream from three-fourths ton to 1½ tons of solid matter.

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The slop was essentially a corn or rye extract, containing all the ingredients of the grains except starch (which had been removed in the form of alcohol and carbon dioxide) in approximately the same proportions that the grains originally contained them. The following table of analyses of these grains, by Richardson, is taken from Thorpe's Dictionary of Applied Chemistry, vol. 1 (1890), page 490:

TABLE 1.—*Average analyses of corn and rye.*

[Based on 114 analyses of corn and 57 analyses of rye.]

| Constituent. | Corn. | Rye. |
|---|---|---|
| Water | 10.0 | 8.7 |
| Nitrogen substance | 10.5 | 11.3 |
| Fat | 5.2 | 1.9 |
| Carbohydrates | 70.7 | 74.5 |
| Fiber | 2.1 | 1.5 |
| Ash | 1.5 | 2.1 |
| | 100.0 | 100.0 |

As corn and rye contain about 55 and 45 per cent, respectively, of starch, the slop will receive 35 to 45 per cent of the grain as solid matter.

TABLE 2.—*Solid matter of corn and rye found in distiller's slop.*

| Constituent. | Corn | Rye. |
|---|---|---|
| Nitrogenous substance | 10.5 | 11.3 |
| Fat | 5.2 | 1.9 |
| Carbohydrates | 15.7 | 29.5 |
| Fiber | 2.1 | 1.5 |
| Ash | 1.5 | 2.1 |
| | 35.0 | 46.3 |

As about 6.7 parts of water are used to 1 part of grain in the distillery processes, it is evident that the slop contained something less than 10 per cent—probably about 5 per cent—of solid matter.

Of the constituents named, those containing nitrogen make up the tissue-forming protein so important in animal food. Carbohydrates, fat, and fiber, digestible in greater or less degree, are producers of energy and fat. By the extraction of the starch the proportional content of protein is greatly increased, and the solid matter of distillery slop when separated from the water and dried thus becomes a valuable concentrated animal food. The ash also, chiefly potassium phosphate, has some food value.

Since these constituents have been taken largely from the soil in producing the grain, it is obvious that they will be suitable for use as a compost, which, by decay, would return to the soil much of the material taken from it. The use of these substances as food for animals, however, possesses much the greater monetary value.

Additional information regarding the constitution of distillery effluents is furnished by the following analyses of the slop, or "pot ale," of English distilleries, adapted from Trades Waste: Its Treatment and Utilization, by W. Naylor:

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TABLE 3.—*Analyses of pot ale from English distilleries.*[a]

[Parts per million.]

SOUCIL AND HARVIE'S DISTILLERIES.

| Constituent. | Soucil (Paisley).[b] | Harvie's.[c] |
|---|---|---|
| Dissolved matters: | | |
| Total solids | 39,378 | 28,955 |
| Organic carbon | 17,057 | 10,008 |
| Organic nitrogen | 2,373 | 2,041 |
| Ammonia | 180 | 90 |
| Nitrogen as nitrites and nitrates | 0 | 0 |
| Total combined nitrogen | 2,522 | 2,115 |
| Suspended matters: | | |
| Mineral | 836 | 53 |
| Organic | 33,372 | 2,776 |
| Total | 34,208 | 2,829 |

[a] Naylor, op. cit., p. 152. [b] July 21, 1870. [c] March 15, 1872.

CRUDE SOUR POT ALE, SOURCE UNKNOWN.[a]

[Parts per million.]

| | |
|---|---|
| Free ammonia | 81 |
| Albuminoid ammonia | 55 |
| Chlorine | 388 |
| Mineral solids | 2,100 |
| Volatile solids | 23,850 |
| Total solids | 25,950 |

POT ALE, SOURCE UNKNOWN.[b]

[Parts per million.]

| | |
|---|---|
| Total solid matter (soluble) | 31,300 |
| Ash | 7,210 |
| Phosphoric acid | 1,990 |
| Saline ammonia | 100 |
| Albuminoid ammonia | 890 |
| Sugar | 400 |
| Carbohydrates, aldehydes, and organic acids (lactic and succinic) | 14,700 |
| Oxygen absorbed in four hours | 1,270 |

It would appear from these analyses that most of the suspended matter had been removed from all samples except that taken from the Soucil distillery. They indicate that nearly half of the solid matter of the slop is in solution, and that the total solids amount to between 5 and 10 per cent. The varying nitrogen values indicate that in some samples decomposition of nitrogenous matter had begun. The high values of nitrogenous matter and carbohydrates and especially the high ratio of nitrogenous to nonnitrogenous material argue well for the food value of the slop.

Almost the whole substance being organic, subject to putrefaction, and undergoing secondary fermentations, the ordinary sewage tests, both chemical and bacteriological, were considered suitable for tracing the effect of such an effluent upon the stream at Lynchburg.

[a] Naylor, op. cit., p. 153. [b] Ibid, p. 149.

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## EFFECT OF POLLUTING EFFLUENTS ON THE STREAM.

A reconnaissance of the East Branch of Little Miami was made from Lynchburg to Fayetteville, a distance of about 9 miles. At suitable intervals samples were taken for chemical analysis, and field tests for dissolved oxygen were made. In addition, plates were made in the field for total bacterial count on agar, for count of acid-forming bacteria on lactose litmus agar, and cultures of strong agar were made for subsequent transplanting and examination for the colon bacilli.

The reconnaissance developed the following physical evidences of pollution:

1. The condition of the stream above the distillery was very good. No evidence of pollution was apparent. The water was generally clear and nearly colorless.

2. The stream waters were colored a light yellow upon the entrance of the distillery waste. This yellow cast was noticeable for perhaps a mile, giving way gradually to a dark murky appearance, such as is commonly ascribed to stagnant water. The stream presented this darker appearance for about 6 miles.

3. A slimy sediment (or possibly a growth of some organism) covered the stream bed for 6 or 7 miles below the distillery. Near Lynchburg this was yellow and heavy. It decreased in amount downstream and changed in color to a dark brown or green.

4. At Bateman Bridge, 3 miles below the distillery, and at St. Martins Bridge, 6 miles below, the stream banks were edged with numbers of small dead fish.

5. An odor of putrefaction was very distinct a few yards from the stream at the two points above mentioned.

The stream, when examined, was somewhat above its average stage of flow. The foregoing conditions would, of course, be accentuated with decrease in flow. Fortunately the distillery is closed from July to October, inclusive. During the season of lowest flow, therefore, pollution is obviated. The difficulty is greatest during the late fall and early winter.

It was stated by a resident 6 miles below Lynchburg that the stench from the creek is at times so great as to be very offensive. Others stated that during the distillery season there is no fishing between Lynchburg and Fayetteville, but that during the summer numerous carp can be caught. At Fayetteville there were no visible evidences of pollution when the reconnaisance was made.

The results of the chemical and bacteriological determinations, together with the estimated dilution of the distillery effluent by the stream waters, are shown by the accompanying table. The chemical constituents were determined as follows: Dissolved oxygen, by the Winkler method in the field; oxygen consumed, by permanganate method, boiling five minutes; organic nitrogen, by the Kjeldahl method; free ammonia, by the distillation method; chlorine, by titration with silver nitrate, potassium chromate indicator; alkalinity, by lacmoid, boiling; solids, in platinum, drying at 100° C.; loss on ignition, by three-minute ignition at a shade under dull-red heat.

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TABLE 4.—*Effect on East Branch, Little Miami River, of effluent from distillery at Lynchburg, Ohio.*

[Chemical constituents expressed in parts per million.]

| | Dam above distillery. | Ford below distillery. | Lower bridge at Lynchburg. | Bateman Bridge. | St. Martins Bridge. | Fayetteville Bridge. |
|---|---|---|---|---|---|---|
| Numbers of samples | 4292, 4286 | 4293, 4287 | 4291, 4297 | 4294, 4288 | 4289, 4295 | 4290, 4296 |
| Distance below distillery | ..... | 75 yards. | 0.5 mile. | 3 miles. | 6 miles. | 9 miles. |
| Dilution of distillery waste | ..... | 1 in 150 | 1 in 150 | 1 in 250 | 1 in 300 | 1 in 350 |
| Dissolved oxygen | 7.6 | 5.9 | 4 | 2.3 | 1.4 | 6.9 |
| Oxygen consumed | 5.46 | 41.26 | 13.24 | 10.89 | 52 | 9.16 |
| Organic nitrogen: | | | | | | |
| Total | .75 | 6.59 | 2.09 | 1.49 | 15.13 | .83 |
| Dissolved | .66 | 2.58 | .85 | 1.16 | 8.02 | .8 |
| Suspended | .09 | 4.01 | 1.24 | .33 | 7.11 | .03 |
| Ammonia, free | .05 | .05 | .17 | 1.6 | 4.62 | .14 |
| Chlorine | 4 | 3.5 | 5 | 3.7 | 7.2 | 5 |
| Alkalinity | 183 | 201 | 205 | 187 | 238 | 184 |
| Solids: | | | | | | |
| Total | 289 | 425 | 305 | 272 | 483 | 282 |
| Dissolved | 272 | 346 | 294 | 266 | 431 | 273 |
| Suspended | 17 | 79 | 11 | 6 | 52 | 4 |
| Loss on ignition: | | | | | | |
| Total | 67 | 171 | 74 | 70 | 238 | 68 |
| Dissolved | 61 | 112 | 63 | 59 | 172 | 73 |
| Suspended | 6 | 59 | 11 | 11 | 66 | None. |
| Number of bacteria per c.c. | 5,200 | 172,000 | 47,000 | 143,000 | 473,000 | 2,000 |
| Acid-forming bacteria in 5 c.c. (lactose litmus agar plate). | Absent. | Absent. | Absent. | Absent. | (a) | Absent. |
| Colon bacilli in 1 c. c. (strong agar culture). | Absent. | Absent. | Absent. | Present. | Present. | Absent. |

a Overgrown.

The results for St. Martins Bridge are far out of proportion to the others. There is almost no dissolved oxygen; oxygen consumed is 9.5 times the normal; suspended organic nitrogen is 79 times the normal; dissolved organic nitrogen is 12 times the normal; total organic nitrogen is 20 times the normal; free ammonia is 92 times the normal; chlorine is 1.8 times the normal; alkalinity is 1.3 times the normal; total solid matter is 1.67 times the normal; dissolved matter is 1.58 times the normal; total suspended matter is 3.06 times the normal; the loss on ignition is 3.6 times the normal for total, 2.8 for dissolved, and 11 for suspended solid matter; bacteria are 91 times as numerous as above the distillery. Colon bacilli were present in 1 cubic centimeter; the water had a dark, stagnant appearance; stench was noticeable some yards from stream; numbers of small dead fish were found lining the banks. The conditions at this place, 6 miles below point of pollution, constitute a very serious menace to property values, and render the stream unfit for use. These conditions are unusual and are not considered in the following discussion of normal pollution, and may be easily explained on the supposition that a few hours before the samples were taken a large amount of matter was discharged from the pool of filth at the distillery and had just reached the St. Martins Bridge.

In order to trace the diminution of evidences of pollution and the progress of the purification of the distillery refuse as it passes downstream, the results of analyses have been reduced to show percentage of normal values, the stream at the dam above the distillery being taken as normal. The results of this reduction are shown numerically in the following table:

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TABLE 5.—*Percentage variation from normal in constituents determined in water taken at certain points on East Branch, Little Miami River.*

[Ingredients in water at dam above distillery taken as normal, or 100 per cent.]

| | Ford below distillery. | Lower bridge at Lynchburg. | Bateman Bridge. | St. Martins Bridge. | Fayetteville Bridge. |
|---|---|---|---|---|---|
| Dissolved oxygen | 78 | 53 | 30 | 18 | 91 |
| Oxygen consumed | 756 | 242 | 199 | 952 | 108 |
| Organic nitrogen: | | | | | |
| Total | 879 | 279 | 199 | 2,017 | 111 |
| Dissolved | 391 | 129 | 176 | 1,215 | 121 |
| Suspended | 4,456 | 1,378 | 370 | 7,900 | [illegible] |
| Ammonia, free | 100 | 340 | 3,200 | 9,240 | [illegible] |
| Chlorine | 88 | 125 | 92 | 180 | 125 |
| Alkalinity | 110 | 112 | 102 | 130 | 104 |
| Solids: | | | | | |
| Total | 147 | 106 | 94 | 167 | 97 |
| Dissolved | 127 | 108 | 98 | 158 | 102 |
| Suspended | 465 | 65 | 35 | 306 | [illegible] |
| Loss on ignition: | | | | | |
| Total | 255 | 114 | 104 | 355 | 101 |
| Dissolved | 184 | 103 | 97 | 282 | ..... |
| Suspended | 983 | 183 | 183 | 1,100 | ..... |
| Bacteria per c. c | 3,308 | 904 | 2,750 | 9,096 | [illegible] |

As the slop entering the creek is heavily charged with solid matter, suspended and in solution, nearly all of which is organic, it is to be expected that the total dissolved and suspended solids and losses on ignition would rise suddenly on the entrance of the distillery refuse. The fall in content of these matters, particularly those in suspension, during the first half-mile below the distillery, indicates that nearly all suspended matter is deposited upon the stream bed in that distance. This is evidenced by the heavy yellow sediment readily noticeable and gradually diminishing in quantity going downstream. The reduction in dissolved solids is also fairly rapid, in the first 3 miles being reduced to a trifle less than that above the distillery.

At Bateman Bridge and Fayetteville the total solid matter is less than above the distillery, and the content of volatile solids is only 4 per cent greater at Bateman Bridge and 1 per cent greater at Fayetteville. So far as these tests indicate, therefore, the variations from normal pollution is inappreciable more than three miles below the distillery (at Bateman Bridge), the stream having almost entirely purified itself by natural means. The stream has a moderate flow and consists of a succession of comparatively deep pools connected by rapids. These pools apparently act as a crude form of septic tank, and oxygen robbed from the stream by putrefying organic matter is gradually restored by aeration in the rapids.

The chlorine and alkalinity determinations serve only to show that the polluting effluent is somewhat higher in chlorine and alkalinity than the normal stream water. The chlorine seems to rise and fall in a manner that can not be attributed to any influence of the distillery refuse. The influence of the slop in increasing the alkalinity of the stream was first viewed with surprise, it being known that the slop as it comes from the still is distinctly acid. Tests made afterward, however, brought to light the fact that upon standing several days the slop changes (with laemoid indicator) from an acid to a strongly alkaline liquor. The changes in alkalinity downstream from Lynchburg corroborate the conclusions already reached from the determination of solids.

The organic-nitrogen determinations are parallel with those previously discussed, inasmuch as they show an immense increase in organic matter with the entrance of the distillery

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refuse, followed by a gradual reduction in the pollution thus caused. Bateman Bridge, however, does not mark the limit of pollution indicated by these determinations. At that point the organic nitrogen is still twice as great as above the distillery, that in suspension showing the greatest proportional reduction. At Fayetteville the organic nitrogen is but little above the normal.

What has been said regarding organic nitrogen applies also to the oxygen-consumed test, an index to carbonaceous matter. The avidity for oxygen due to the distillery refuse has been nearly satisfied at Bateman Bridge, a reduction of less than one-third the normal oxygen-consuming power occurring in the 6 miles traversed between that point and Fayetteville.

The two chemical tests not already discussed, dissolved-oxygen and free-ammonia, are of more than usual interest in this case, because they mark the crisis in putrefactive action or the breaking up of carbonaceous and nitrogenous organic compounds into gases, water, and soluble mineral substances. The dissolved-oxygen tests, showing immediate decrease of a large proportion of free oxygen on the advent of the distillery refuse, serve to corroborate the unusual oxygen-consuming power of such refuse, as indicated by the oxygen-consuming tests. Bateman Bridge shows the lowest value for dissolved oxygen which can be attributed to normal state of pollution. It may be assumed, therefore, that the carbonaceous material has at this point been nearly all oxidized, further action of this kind being more than compensated for by oxygen naturally supplied to the stream waters. A gradual increase in dissolved oxygen is assumed to Fayetteville, where it is practically normal.

Comparing the stream action with a sewage-disposal system, Bateman Bridge may be looked upon as at the exit of a septic tank, further action being similar in result to that of oxidizing filtration. The diminution of dissolved oxygen may account for the death of the fish.

The tests for free ammonia indicate the absence of advanced putrefaction in the refuse that enters the stream. The nitrogenous matter is gradually broken up until a crisis is reached, as before indicated, near Bateman Bridge, from which point to Fayetteville the free ammonia decreases from 32 to 2.8 times the normal.

The bacterial counts indicate that the slop refuse contains a large number of organisms, probably such as produce secondary ferments; that stream conditions are not favorable to such organisms, and that they are reduced in number thereby; that the organisms originally present give place to bacteria which thrive on putrefying organic matter; that these bacteria assist largely in the purification of the stream and are not found, extensively at least, in the purified water at Fayetteville. The significance of the tests for B. coli communis is somewhat doubtful. It will be noted that this organism was found at but two points, Bateman Bridge and St. Martins Bridge, at which places all evidences of putrefaction were greatest. It is probable that its presence is due to the passage of a charge of concentrated filth from the cattle pens.

The important results of the reconnaissance of East Branch of Little Miami River from Lynchburg to Fayetteville may be summed up as follows:

1. The pollution by 1 part of distillery refuse in 150 parts of water is shown by a heavy sediment, deposited principally in the first mile below the distillery.

2. Such pollution causes a disagreeable stench for 2 or 3 miles along the stream and probably causes the death of fish.

3. The putrefaction of the polluting material in general is about complete 3 miles below the distillery, the stream at that point being similar in character to the dilute effluent of a septic tank.

4. Nine miles below Lynchburg the stream is apparently nearly as pure as it is above the distillery.

5. Large amounts of refuse discharged into the stream at other than flood stages produce extreme pollution, cause a strongly disagreeable stench, kill fish, and, in a word, render the stream unfit for its natural uses for more than 6 miles below the distillery.

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## DISPOSAL OF DISTILLERY EFFLUENT WITHOUT STREAM POLLUTION.

To dispose of the distillery refuse without polluting the stream, four easily apparent methods could be used with more or less success: Filtration, precipitation, fermentation, and evaporation.

### FILTRATION.

Simple filtration for such refuse has never been attended with satisfactory results. Nearly one-half of the solid matter being in solution, mere straining can not produce satisfactory purification. Bacterial filters manipulated with special care and unusual precautionary measures on an experimental scale have given an effluent which does not produce appreciable pollution, but the tendency of distillery slop to sour by rapid growth of acid ferments makes such a method of disposal extremely difficult. Naylor describes a method of bacterial treatment which depends upon the principle that—

> the activity of one micro-organism is arrested by the introduction of media suitable for the rapid development of other competitive forms. * * * Putrid sewage, or sewage sludge, is introduced, the active anaërobic organisms in which come into competition with the acid-producing bacteria, and in a short time the action of the latter ceases; moreover, the ammonia and other unstable compounds in the sewage neutralize the acids if already present, the resulting putrid liquid becoming quite amenable to treatment on bacterial filters. The treatment as a whole is similar to septic treatment, but the "septic" tank is in this case not used for the purpose of liquefying sludge, but for that of rendering inert the acid-forming organisms. It is therefore better described as an antisouring tank.[a]

Experimental tests were made upon a small quantity of crude sour "pot ale," or slop, which was neutralized with lime, passed through a tank containing sewage, and then subjected to bacterial filtration. A decrease of 96.5 per cent in free ammonia, 88.3 per cent in albuminoid ammonia, 16.7 per cent in mineral solids, and 97 per cent in volatile solids was thus effected.[b] This may be considered a substantial purification. Naylor's method was applied with success to the waste from the brewery of the Hook Norton Brewery Company, Hook Norton, Banbury, England, and plants of similar character have been installed at several breweries in England, not, however, with universal success. The failure of such a process at the Old Brewery, Rothingham, resulted in experimentation on a large scale by H. McLean Wilson for a better method of treatment. He was able to secure a satisfactory effluent at this brewery only under the following process: (*a*) Yeast was excluded; (*b*) milk of lime in quantity equal to 45 grains per gallon of lime (643 parts per million) was added to produce a neutral liquor; (*c*) sludge was removed at frequent intervals; (*d*) the supernatant from anti-acid tanks was passed through double-contact ash filters; (*e*) ash-filter effluent was treated in a coke sprinkler in intermittent doses every five minutes for eight hours, amounting to 140 gallons per square yard per day; (*f*) effluent from coke sprinkler was strained through sand. This process resulted in purification of 96 per cent as measured by albuminoid ammonia, or 93 per cent as measured by oxygen absorbed in four hours at 80° F.[c]

Brewery liquors are of the same general character as distillery slops, though more dilute. It is probable, therefore, that the successful treatment of distillery liquors by such means as those described requires merely their adaptation to local conditions.

James Hendrick, in transactions of the Aberdeen congress, 1900, describes experiments with distillery refuse upon contact beds without preliminary treatment. The purification as measured by albuminoid ammonia and by oxygen absorbed in four hours at 80° F., respectively, was as follows: Seven contacts, 5 with coke followed by 2 with sand, 98.9 and 98.7 per cent; first six contacts, 97 and 98 per cent; first five, 96.4 and 97.9 per cent; first four, 89 and 95 per cent; first three, 73 and 65 per cent; first two, 40 and 61 per cent; first contact, 20 and 23 per cent. The last four effluents contained nitrates, as did the effluent obtained by Wilson in the brewery experiments.

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[a] Naylor, W., Trades Waste, 1902. p. 153.

[b] Naylor, op. cit., p. 153.

[c] Wilson, H. McLean, Jour. Royal Sanitary Inst., vol. 25, pt. 3, p. 574 et seq.

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The results of these English experiments, while indicating the practicability of bacterial filtration, with or without preliminary treatment, as a means of purifying such waste liquors as are produced by breweries and distilleries, demonstrate clearly that such a method of purification is very difficult and requires an extensive and costly plant and constant, intelligent supervision. The sludge produced in antisouring tanks is considerable and has but little actual value as a manurial compost. It may readily be the cause of a nuisance if not frequently removed and so disposed that its offensive odor shall not be objectionable.

Above all other objections to bacterial filtration of these wastes is the primary fact that this method is one of destruction and precludes the possibility of the recovery of any valuable by-products which they may contain. Distillery slop, as is well known, has appreciable value as a compost and a much greater intrinsic worth as an animal food. The high dilution of the valuable material and the fact that it is largely in solution prevent its more general use in either or both of the ways mentioned. The food or manurial value of the slop depends upon its content of organic matters, chief among which are the valuable compounds of nitrogen grouped under the term protein. The same matters form the element of nuisance in stream pollution by putrefaction after they enter bodies of water not relatively very large. Treatment in bacterial filters depends for its success upon the action of the bacteria-laden filtering medium upon the same constituents. In such treatment, however, the valuable material is regarded merely as an element to be destroyed as such, and is changed into gaseous, mineral, or stable organic compounds. This treatment is regarded as successful only in proportion as the food or manurial value of the organic carbon and nitrogen is destroyed. It is effective as a preventive of stream pollution only in so far as it renders devoid of value a product which with proper treatment may be made a source of considerable revenue. It follows that such a system must necessarily be a source of constant expense for which no direct monetary return can be expected. It is therefore a method of treatment to be employed only when more economic purification can not be accomplished. This being the case, and this field having already been well exploited in England, no experiments in filtration were made in connection with the investigation at Lynchburg.

## PRECIPITATION.

Chemical precipitation as applied to distillery refuse is, in principle, a purification system of doubtful efficiency and economy. In practice, so far as known, it has never proved even fairly satisfactory in either particular. In his experiments upon brewery waste at the Old Brewery, Rothingham, Wilson tried lime, copperas, manganate of soda, and alumino-ferric in various amounts and with varied combinations. As compared to lime alone, the use of the other precipitants served to hasten deposition of the precipitate, but made no practical difference in the effluent.[a] In every case the supernatant was unfit to discharge into a stream because of the failure of the precipitants to throw out of solution the large proportion of organic matter it held. In other words, the effect was similar to that of mechanical filtration or straining. These experiments show the futility of attempts to purify brewery or distillery wastes by means of the precipitants in common use. To be efficient as a means of purifying such liquors the precipitation must be carried on by means of a substance that will throw the organic matter out of solution. Even were such a substance known, the problem of disposing of tons of sludge daily would be left for solution. In the interests of economy the initial cost of the precipitant should be a minimum and its composition should be such that the sludge produced will have a maximum value. The solids of distillery slop have value either as fertilizer or as food stuff for stock, and in order to make the value of the sludge greatest the precipitant should also have one of these values, preferably the latter, since in that lies the greater value of the refuse. It is evident that the greatest economy might be secured by a high-priced precipitant that would produce a more valuable sludge. It is really the difference between the cost of precipitant and value of sludge that should be taken as a criterion of the economy of the process.

[a] Jour. Royal Sanitary Inst., vol. 25, pt. 3, p. 574.



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A successful—i. e., economical and efficient—purification of distillery refuse by chemical precipitation must therefore be accomplished by means of some substance as yet unknown that will precipitate the organic matter in solution as well as the suspended matter, and that shall itself be a suitable constituent of a fertilizer or a food stuff. Experimentation along the line of chemical precipitation should therefore include primarily a search for such a precipitant. In view of the manifest difficulties attending such experimentation, the improbability of success, and the success attending research in other lines, no attempt was made to exploit this method of purification.

## FERMENTATION.

It might be inferred from the rapid souring of distillery slops by secondary fermentations that these could be utilized in the disposal of the slop by the production of lactic or acetic acids or some other resultant of fermentation. Such use has been made of brewery liquors for the preparation of malt vinegar.[a] Objections would be the great storage area required; the impurity of the product, several different fermentations being active; the great dilution of a product so obtained; the general low market price of products that could probably be so obtained, and the residual sludge from such a process, composed of matters otherwise valuable as a foodstuff, but rendered useless for such purpose by the fermentation process.

Here also the probabilities of success lying rather with another process, this means of disposal was abandoned without experimentation.

## EVAPORATION.

The increased efficiency of modern evaporating apparatus suggested the possibility of conserving all the valuable food material of the slop by evaporation. This process possesses intrinsic merit absent in the other methods of disposal considered. The products of an evaporator would be:-(*a*) A distillate of nearly pure water, incapable of polluting the stream and probably more valuable than the water of a natural supply for use in the distillery processes; (*b*) the solid matter of the slop, practically unchanged in composition. The basic principle of this method is practically ideal. Nearly perfect purification is attained by the conservation of the valuable material in the refuse. As the theory of this method of disposal was extremely attractive, and as a rough estimate of costs and values indicated large economic possibilities, it was investigated in detail.

### AMOUNT OF SLOPS AND RECOVERABLE SOLID MATTER.

Table 6 shows the quantity of slops, both for rye and corn distillation, discharged at the brewery at Lynchburg, arranged by daily discharge and by discharge per bushel of grain mashed. The figures given represent, it is believed, within about 5 per cent the actual conditions and are therefore sufficiently accurate to be used as a basis of costs and values in estimating the economic possibilities of any disposal system.

[a] Koller, The Utilization of Waste Products, p. 26.

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TABLE 6. *–Daily discharge of slops at Lynchburg distillery.*

| Source. | Slop (designation). | Total discharge. | | Discharge per bushel of grain mashed. | |
|---|---|---|---|---|---|
| | | Gallons. | Pounds. | Gallons. | Pounds. |
| Direct from still | Corn 1 | 77,000 | 651,600 | 44.0 | 372 |
| Through strainer | Corn 1a | 16,300 | 136,900 | 9.3 | 78 |
| To screen | Corn 1b | 60,700 | 514,700 | 34.7 | 294 |
| Through screen | Corn 2 | 37,300 | 314,700 | 21.3 | 180 |
| Over screen | Corn 3 | 23,400 | 200,000 | 13.4 | 114 |
| Vat supernatant | Corn 4 | 7,300 | 60,700 | 4.2 | 35 |
| Vat sludge | Corn 5 | 30,000 | 254,000 | 17.1 | 145 |
| From presses | Corn 6 | 19,500 | 163,300 | 11.1 | 93 |
| Pressed feed | Corn 7 | ..... | 36,700 | ..... | 21 |
| Dried feed | Corn 8 | ..... | 17,500 | ..... | 10 |
| To screen | Rye 1 | 61,500 | 542,200 | 44.2 | 377 |
| Through screen | Rye 2 | 44,900 | 380,300 | 32.3 | 273 |
| Over screen | Rye 3 | 16,600 | 143,900 | 11.9 | 103 |
| Vat supernatant | Rye 4 | 14,900 | 125,200 | 10.7 | 90 |
| Vat sludge | Rye 5 | 30,000 | 255,100 | 21.6 | 183 |
| From presses | Rye 6 | 13,000 | 109,300 | 9.3 | 79 |
| Pressed feed | Rye 7 | ..... | 34,600 | ..... | 25 |
| Dried feed | Rye 8 | ..... | 11,600 | ..... | 8.3 |

As a means of estimating the amount of recoverable foodstuffs in the slop, hourly composite samples representing the entire working day were taken. Selected samples of the present slop product after screening, after pressing, and after the final drying were also taken for purposes of comparison and computation. Partial analyses of these samples were made in the laboratory of the Ohio State board of health, at Columbus, the results of which are shown in table 7.

The evaporation was effected by means of a water bath. A preliminary drying was given at 100° C. and a final drying at about 135° C. The figures show, therefore, values somewhat less than would be obtained by an accurate determination of solids under more favorable conditions. They will approximate very nearly, however, the true values for solid matter recoverable by evaporation.

In table 8 the proportional composition of the solid matter is shown, this having been prepared from table 7.

The amount of recoverable matter is shown in pounds per day in table 9, and in pounds per bushel of grain mashed in table 10.

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TABLE 7.—*Recoverable solid matter in classified distillery slops.*

| Source. | Slop (designation). | Sample No. | Dissolved. | | | Suspended. | | | Total. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Volatile. | Fixed. | Total. | Volatile. | Fixed. | Total. | Volatile. | Fixed. | Total. |
| To screen [a] | Corn 1b. | 39 | 19.5 | 2.1 | 21.6 | 24.9 | 0.5 | 25.4 | 44.4 | 2.6 | 47.0 |
| Through screen [a] | Corn 2. | 40 | 19.9 | 2.2 | 22.1 | 10.3 | .2 | 10.5 | 30.2 | 2.4 | 32.6 |
| Over screen [b] | Corn 3. | 42 | | | | | | | 94.7 | 3.1 | 97.8 |
| From presses [a] | Corn 6. | 41 | 18.9 | 2.2 | 21.1 | 1.3 | Tr. | 1.3 | 20.2 | 2.2 | 22.4 |
| Pressed feed [b] | Corn 7. | 43 | | | | | | | 426.4 | 7.2 | 433.6 |
| Dried feed [b] | Corn 8. | 44 | | | | | | | 917.3 | 16.7 | 934.0 |
| To screen [a] | Rye 1. | 34 | 19.8 | 1.9 | 21.7 | 27.4 | .3 | 27.7 | 47.2 | 2.2 | 49.4 |
| Through screen [a] | Rye 2. | 35 | 18.3 | 1.8 | 20.1 | 11.9 | .2 | 12.1 | 30.2 | 2.0 | 32.2 |
| Over screen [b] | Rye 3. | 37 | | | | | | | 89.6 | 2.8 | 92.4 |
| Vat supernatant [a] | Rye 4. | 32 | 18.2 | 1.8 | 20.0 | .1 | Tr. | .1 | 18.3 | 1.8 | 20.1 |
| From presses [a] | Rye 6. | 33 | 19.9 | 1.9 | 21.8 | 1.4 | Tr. | 1.4 | 21.3 | 1.9 | 23.2 |
| Pressed feed [b] | Rye 7. | 38 | | | | | | | 307.3 | 5.1 | 312.4 |
| Dried feed [b] | Rye 8. | 36 | | | | | | | 851.2 | 17.7 | 868.9 |

[a] Grams per liter. [b] Grams per kilo.

TABLE 8.—*Proportional composition of recoverable solid matter in classified distillery slops.*

[Per cent of total solid matter.]

| Source. | Slop (designation). | Sample No. | Dissolved. | | | Suspended. | | | Total. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Volatile. | Fixed. | Total. | Volatile. | Fixed. | Total. | Volatile. | Fixed. | Total. |
| To screen | Corn 1b. | 39 | 41.5 | 4.5 | 46.0 | 53.0 | 1.0 | 54.0 | 94.5 | 5.5 | 100 |
| Through screen | Corn 2. | 40 | 61.0 | 6.7 | 67.7 | 31.6 | .7 | 32.3 | 92.6 | 7.4 | 100 |
| Over screen | Corn 3. | 42 | | | | | | | 96.8 | 3.2 | 100 |
| From presses | Corn 6. | 41 | 84.4 | 9.8 | 94.2 | 5.8 | Tr. | 5.8 | 90.2 | 9.8 | 100 |
| Pressed feed | Corn 7. | 43 | | | | | | | 98.3 | 1.7 | 100 |
| Dried feed | Corn 8. | 44 | | | | | | | 98.2 | 1.8 | 100 |
| To screen | Rye 1. | 34 | 49.1 | 3.8 | 43.9 | 55.5 | .6 | 56.1 | 95.6 | 4.4 | 100 |
| Through screen | Rye 2. | 35 | 56.8 | 5.6 | 62.4 | 37.0 | .6 | 37.6 | 93.8 | 6.2 | 100 |
| Over screen | Rye 3. | 37 | | | | | | | 97.0 | 3.0 | 100 |
| Vat supernatant | Rye 4. | 32 | 90.5 | 9.0 | 99.5 | .5 | Tr. | .5 | 91.0 | 9.0 | 100 |
| From presses | Rye 6. | 33 | 85.8 | 8.2 | 94.0 | 6.0 | Tr. | 6.0 | 91.8 | 8.2 | 100 |
| Pressed feed | Rye 7. | 38 | | | | | | | 98.4 | 1.6 | 100 |
| Dried feed | Rye 8. | 36 | | | | | | | 98.0 | 2.0 | 100 |

TABLE 9.—*Weight, in pounds, of solid matter discharged daily in classified distillery slops.*

| Source. | Slop (designation). | Dissolved. | | | Suspended. | | | Total. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Volatile. | Fixed. | Total. | Volatile. | Fixed. | Total. | Volatile. | Fixed. | Total. |
| To screen | Corn 1b. | 12,350 | 1,350 | 13,700 | 15,800 | 300 | 16,100 | 28,150 | 1,650 | 29,800 |
| Through screen | Corn 2. | 6,200 | 700 | 6,900 | 3,200 | 100 | 3,300 | 9,400 | 800 | 10,200 |
| Over screen | Corn 3. | | | | | | | 18,950 | 650 | 19,600 |
| From presses | Corn 6. | 3,150 | 350 | 3,500 | 200 | Tr. | 200 | 3,350 | 350 | 3,700 |
| Pressed feed | Corn 7. | | | | | | | 15,650 | 250 | 15,900 |
| Dried feed | Corn 8. | | | | | | | 15,550 | 250 | 15,800 |
| To screen | Rye 1. | 10,200 | 950 | 11,150 | 14,100 | 150 | 14,250 | 24,300 | 1,100 | 25,400 |
| Through screen | Rye 2. | 6,850 | 700 | 7,750 | 4,500 | 50 | 4,550 | 11,350 | 750 | 12,100 |
| Over screen | Rye 3. | | | | | | | 12,900 | 400 | 13,300 |
| From presses | Rye 6. | 2,150 | 200 | 2,350 | 150 | Tr. | 150 | 2,300 | 200 | 2,500 |
| Pressed feed | Rye 7. | | | | | | | 10,600 | 200 | 10,800 |
| Dried feed | Rye 8. | | | | | | | 10,500 | 200 | 10,700 |

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TABLE 10.—*Weight, in pounds, of solid matter discharged daily in classified distillery slop per bushel of grain mashed.*

| Source. | Slop (designation). | Dissolved. | | | Suspended. | | | Total. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Volatile. | Fixed. | Total. | Volatile. | Fixed. | Total. | Volatile. | Fixed. | Total. |
| To screen | Corn 1b. | 7.06 | 0.77 | 7.83 | 9.03 | 0.17 | 9.20 | 16.09 | 0.94 | 17.03 |
| Through screen | Corn 2... | 3.54 | .40 | 3.94 | 1.83 | .06 | 1.89 | 5.37 | .46 | 5.83 |
| Over screen | Corn 3... | | | | | | | 10.83 | .37 | 11.20 |
| From presses | Corn 6... | 1.80 | .20 | 2.00 | .11 | Tr. | .11 | 1.91 | .20 | 2.11 |
| Pressed feed | Corn 7... | | | | | | | 8.94 | .14 | 9.08 |
| Dried feed | Corn 8... | | | | | | | 8.89 | .14 | 9.03 |
| To screen | Rye 1... | 7.33 | .68 | 8.01 | 10.13 | .11 | 10.30 | 17.46 | .79 | 18.25 |
| Through screen | Rye 2... | 4.92 | .50 | 5.42 | 3.23 | .04 | 3.27 | 8.15 | .54 | 8.69 |
| Over screen | Rye 3... | | | | | | | 9.27 | .28 | 9.55 |
| From presses | Rye 6... | 1.55 | .14 | 1.69 | .11 | Tr. | .11 | 1.66 | .14 | 1.80 |
| Pressed feed | Rye 7... | | | | | | | 7.61 | .14 | 7.75 |
| Dried feed | Rye 8... | | | | | | | 7.54 | .14 | 7.68 |

From table 9 we find the total solid matter available each day on corn distillation to be 29,800 pounds (corn 1b), less 3,700 pounds (corn 6, used over in fermenting vats), or 26,100 pounds. Of this amount, 15,800 pounds (corn 8) was formerly recovered, leaving a total of 10,300 pounds run into the stream or fed to cattle. Possibly 100 pounds were wasted under the old recovery system. If, therefore, we deduct 300 pounds as waste under the extended system, we have provided a wide margin of safety and still have an increased product of 5 tons a day, or a total product of 12.9 tons a day.

For rye, none of the slop being used over, a proportionally larger product is obtainable. Deducting the 10,700 pounds (rye 8), recovered by the old method from the total of 25,400 pounds (rye 1), and allowing, as in the case of corn, 300 pounds for waste, we have an increased product of 14,400 pounds (7.2 tons), or a total product of 12.55 tons of dry solids.

### METHOD OF EVAPORATION.

The first question arising which will affect the mode of procedure is in relation to the point of application of the evaporation process. What slops shall be evaporated? The stream pollution is caused chiefly by the waste each day of some 10,000 to 15,000 gallons of a fairly thin slop, the supernatant from the settling vats and the waste liquor from the rectifier. The remainder is now recovered or fed to cattle. Will it be more profitable to evaporate only those liquors that cause pollution or to apply the process to the entire slop output of the distillery? This question involves the abandonment of the cattle-fattening industry. It is generally conceded that this industry is financially precarious, being valuable chiefly as a means of disposing of slops. In some years it produces substantial profits; in others there are equally great losses. The cattle must be herded together in sheds, where the spread of communicable diseases is rapid. There is always great danger of loss by fire. Fluctuation in the market value of stock is another element of uncertainty. Although the business averages a small profit, few distillers would not be glad to exchange it for any other method of slop disposal that would not be a continued source of financial loss. Another objection to the cattle business is the great accumulation of manure, which from slop feeding is copious and in a semifluid condition. Great quantities are hauled away by farmers, but there is generally a remainder to cause a nuisance on the spot or to be run into the stream with the thin slops. From these considerations and the knowledge that the cost of evaporation is proportionally less with greater quantities, it is obvious that cattle fattening can well be abandoned if any part of the slop is to be utilized by evaporation.

Suspended matter will retard evaporation, causing a higher temperature for vaporization, forming scum, and having a tendency to adhere to the heating surface. In laboratory tests

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in glass and iron dishes much difficulty was caused by the burning of adhering particles in the evaporation of slops containing considerable suspended matter. Filtered samples of thin slops, such as those coming from the filter presses (corn 6 and rye 6), could be concentrated to contain only 50 per cent of moisture without serious difficulty. Tests on speed of evaporation of rye slops, the most difficult to treat because of the slimy nature of the liquid, showed an inappreciable difference between the speed of evaporation of the first half of equal volumes of distilled water and slop rye 4, the vat supernatant containing 100 parts per million of suspended matter. Rye 6, slop from presses containing 1,400 parts per million of suspended matter, was somewhat slower. A comparison of rye 6 (slop from presses), rye 2 (slop passing through screen), and rye 1 (slop before passing screen) showed that the volumes evaporated in a given time were approximately in the ratio 6:2:1. The suspended solids in these slops are approximately in the ratio 0.05:44:1. Although these experiments were not conducted with sufficient care to warrant great dependence upon numerical relations that might be deduced from them, they prove that the suspended matter seriously interferes with evaporation; that previous to evaporation the slop should be more thoroughly screened than at present; and that the screening should be at least as thorough as that effected by the filter presses.

In the conduct of an evaporation system, therefore, the first process should consist of passing slops rye 1 and corn 1 over a series of rotary or oscillating brass or copper screens. The screens should be designed to separate the slops into a thin liquid containing about 2.15 per cent of dissolved and 0.1 per cent of suspended solids and a thick, pulpy mass containing about 2.15 per cent of dissolved and 10 per cent of suspended solids.

Pl. I gives a view of an approved type of machine designed to filter-press distiller's slop. This machine is composed of 93 plates (one of which is shown in the foreground), which rest upon the iron frame of the press. Any two adjoining plates are separated by a filtering medium (a fine brass screen or piece of stout cloth) and form a filter. The substance to be filtered is introduced through the opening in the center and is forced outward toward the perimeter. The clear liquid passes through the filtering medium and is drained off, while the suspended matter is retained between the plates.

It will be observed in the illustration that the machine is arranged in three sections. The substance to be filtered is introduced at the left end of each section and is distributed to the various plates by a sort of screw conveyor operating in the central aperture. It is customary to force the material into the machine at a pressure of 150 to 200 pounds to the square inch. When the machine is filled in this manner, a further pressure is used to force the plates (which have been up to this time slightly separated) closer together and thus to reduce still further the moisture retained in the coarse material between the plates. This pressure is variously applied. In the illustration the hydraulic piston shown on the right is used for this purpose. A very high pressure is thus attained with consequent high efficiency in drying the suspended matter retained in the filter.

The moisture having been reduced as far as possible, the plates are separated, the caked material within is removed, and the machine is prepared for a new charge.

From this process two products are obtained: First, a thin slop of about the same composition as the thin slop from the screens; second, a damp, caked feed, half moisture and half solid matter. The first of these products should be pumped back to join the thin slop from the screens, the second should be conveyed to a mixer to be joined by the evaporated slop.

The thin slop from the screens should pass to a feed reservoir for the evaporator, where it should be joined by the thin slop from the filter presses and the thin slop from the rectifier, herein referred to as waste A. Waste A is an irregular flow of small amount. On this account it is excluded from the calculations. From this reservoir, in the case of corn distillation, 35,800 gallons will be carried back for use in the fermenters, this use of slop as a diluent in the fermentation process materially increasing the yield of spiritous liquors.

We have now reached that point in the disposal system where evaporation becomes necessary as a means of separating the water from the dissolved solid matter in the dilute slop liquors which are practically free from suspended matter. For this process vacuum

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SMITH-VAILE FILTER PRESS

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multiple-effect machines, of types such as the Yaryan or Chapman, are eminently suitable. The principles involved are primarily: (1) That the temperature at which a liquid will vaporize is decreased by decrease of pressure within the vessel containing it; and (2) after the temperature of a liquid has been raised to the point of vaporization an additional supply of heat is required to vaporize it, which supply of heat increases with decrease in temperature and will be given off when the vapor is condensed to a liquid.

Yaryan's triple-effect vacuum evaporator (fig. 3) may be taken as a type of this class of machines, the general principles of operation being alike in all. This machine consists essentially of three cylindrical chambers or "effects," in each of which is a series of coils of small tubing. Each effect is also provided with a separator to free the concentrated liquor from the vapor before it leaves the effect. A vacuum pump draws the vapor from the last effect and thus automatically regulates the pressures in the various effects. The operation is as follows: Steam is led into the cylindrical chamber surrounding the coils of the first effect, and the liquid to be evaporated is introduced within the first tube of these coils in a small but continuous stream. The surrounding steam immediately causes the liquid to boil, and the steam thus generated causes it to rush through the heated coils, where it becomes more and more concentrated as it progresses. Finally, the mixture of liquid and steam is discharged from the last tube into the separator. The concentrated liquor from the separator of the first effect passes to the coils of the second effect for further concentration. The vapor generated in the first effect passes to the chamber surrounding the coils of the second effect, where it is condensed and gives up its latent heat. The same operation takes place in each succeeding effect, the vapor from the final effect going to the condenser and vacuum pump, a high vacuum being thereby maintained in the coils of the final effect. This reduces the boiling point of the liquor in the coils below that of the surrounding steam, which, condensing, not only gives up its heat to the liquor in the tubes, but forms a vacuum of lesser degree in the next preceding effect. The relative pressure maintained in the various effects is automatically adjusted to accomplish a vaporization of the liquid in each effect, except the first, by means of the vapor generated by its own evaporation in the next preceding effect. The highly concentrated liquor from the final effect is removed by a magma pump as may be desired.

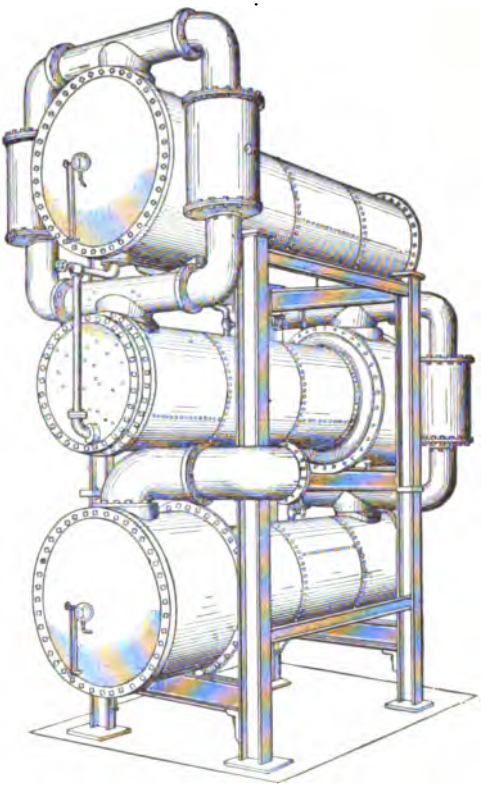

FIG. 3.—Yaryan's triple-effect evaporator.

This utilization of the steam generated by evaporation will accomplish in a triple-effect machine about three times as much evaporation with a given amount of fuel as the ordinary "single-effect" evaporator. Radiation and the expense of maintaining the low pressures will of course reduce the theoretical economy of the machine. It is claimed, however, that

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the Yaryan evaporators in practical operation, assuming that 1 pound of coal will vaporize 8½ pounds of water, will evaporate the following amounts of water with 1 pound of coal: Double effect, 16 pounds; triple effect, 23.5 pounds; quadruple effect, 30 pounds; quintuple effect, 37 pounds.

Advantages of evaporators of this type are rapid circulation of liquid and consequent short time exposure to heat, low temperature of evaporation because of vacuum, and an arrangement by which a small quantity of liquid is exposed to an extensive heating surface. These advantages are of considerable importance in dealing with distillery slops, the organic compounds of which are likely to be broken up by high temperature and long exposure to heat, so as to impair possibly their food value. Within reasonable limits, by suitable arrangement of pressures, the temperature of vaporization may be regulated as desired, and thus any possible injury to recoverable material avoided.

Chief among the disadvantages are the great cost of the machines and their doubtful economy of operation in dealing with highly concentrated liquors.

In connection with the process of evaporation the matter of condensation of exhaust steam must be considered. For the proposition in hand this can be accomplished by about 350,000 gallons daily of cooling water to be used in connection with condensers of ordinary type. At Lynchburg this supply of water can probably be had at the cost of pumping from the adjacent stream, though it may be found necessary to sink shallow wells. As an extreme measure in case of limited water supply, cooling tanks or reservoirs may be constructed in which the water, heated by reason of its use as a condensing agent, may regain its normal temperature, and thus be made ready for use again. By such means an initial supply of water can be used over and over, a loss of only 2 to 10 per cent taking place daily through leakage and evaporation. There are in practical use many types of cooling towers in which artificial air draft or natural radiation is utilized for reducing the temperature. Simple open reservoirs are also used for such purpose, but these are generally considered to be less advantageous than specially constructed towers.

From the evaporation process, including condensation, we shall have two products, the first a magma or evaporated slop of 2,600 gallons on corn and 4,000 gallons on rye; and second, a distillate or condensed steam, amounting to 34,900 gallons on corn or 55,000 gallons on rye. (See table 11.) The distillate, a nearly pure water, is specially suitable for use in the mashing process, for which it has considerably greater value than a natural water. It should therefore be pumped to the cookers.

The magma, containing not more than 75 per cent of moisture (manufacturers of evaporators claim a reduction to 50 per cent moisture), should be passed to a tub and thoroughly mixed with the damp feed from the filter presses preparatory to drying. A cylindrical tub with central revolving vertical shaft having horizontal arms attached will prove a satisfactory mixer.

In this description of the disposal-recovery process we have now reached a point where all the waste from a distillery has been reduced to a pulpy mass of material suitable in composition for cattle feed. It remains only to prepare this for shipping. In the pulpy condition, although it is well adapted for immediate feeding, it is not marketable, because of its large moisture content and its liability to heat and ferment. To prepare it for the market, its moisture content should be reduced to about 10 per cent. In the present food-stuff process at Lynchburg this is accomplished by passing the damp feed from the filter presses through a hot-air drier, the product of the drier being sacked for shipment. With the process we are proposing, this treatment would be insufficient. Even in the present process considerable difficulty is experienced in the caking of the feed and consequent irregular drying. When it is considered that in the proposed process the material to be dried will contain more moisture and that much of it will be in extremely fine grains, it will be obvious that this difficulty would be enormously increased. It is proposed, therefore, to accomplish the drying in two stages. In the first a reduction to about 20 per cent of moisture will be obtained. The material should then be conveyed to a thrasher to break up all cakes formed, and finally to a second drier in which an even drying to a moisture content of 10 per cent or less may be

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accomplished. The usual types of hot-air or steam revolving feed driers and the ordinary feed thrasher would be suitable for this work.

A modern drier of considerable efficiency is shown in fig. 4. It consists essentially of a cylindrical steel shell provided on the interior with longitudinally placed shelves. Near each end of the shell is a steel tire which rests on friction roller wheels. These wheels are rotated by gearing or chain belting and they in turn rotate the shell. The drier as a whole is set on a gentle slope. Its operation is as follows: The wet material is introduced at the higher end by means of an intake hopper and falls to the bottom of the shell. It is then caught by the shelves and elevated by the rotation almost to the top of the shell and is then showered to the bottom again. This cycle is repeated again and again as the material slowly

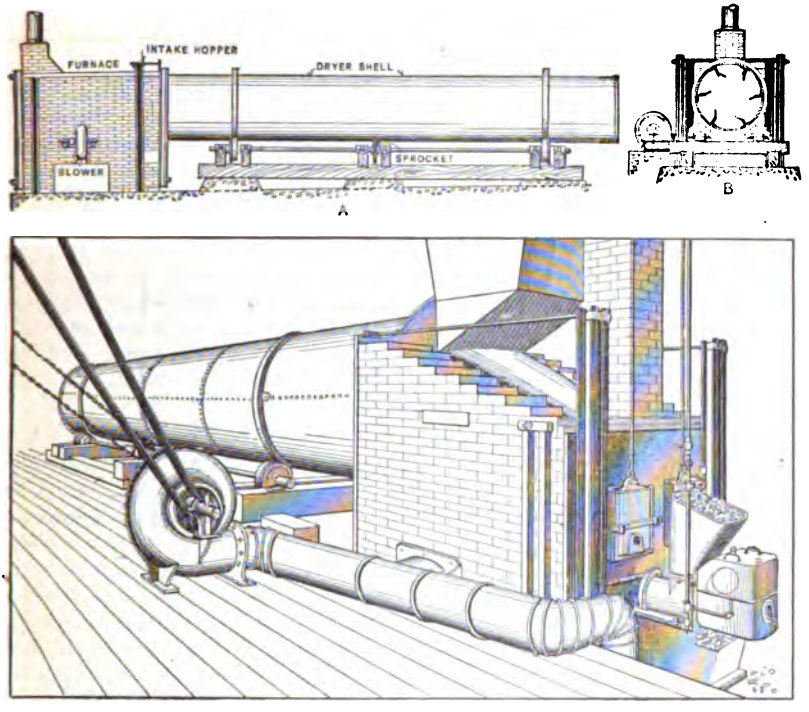


FIG. 4.—American process drier.

travels to the lower end on account of the slope of the machine and the high draft created by the blower. All hot gases pass through the drier on their way to the chimney, and as the material is showered from top to bottom of the shell it is brought in direct contact with the gases, thus accomplishing a rapid and thorough drying.

This drying process is the final preparation for sacking and shipment.

Table 11 shows the probable amount of the various slops and slop products (in pounds and gallons) and the amount of recoverable solids therein (in pounds), arranged by quantity per day, quantity per hour, and quantity per bushel of grain mashed. The figures shown are based upon measurements of quantities at the distillery, laboratory experiments, and general knowledge of the efficiency and capacity of the machinery described. Although these figures are unsubstantiated by practice, no such plant having yet been placed in operation, it is believed that they are fairly accurate and suitable for use in estimating costs and values.

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TABLE 11.—*Probable amount of classified slops and slop products and recoverable matter under proposed system of disposal by evaporation.*

| Source. | Slops and slop products. | | | | | | Recoverable solids | | |
|---|---|---|---|---|---|---|---|---|---|
| | Gallons. | | | Pounds. | | | Pounds. | | |
| | Per day. | Per hour. | Per bushel of grain mashed. | Per day. | Per hour. | Per bushel of grain mashed. | Per day. | Per hour. | Per bushel of grain mashed. |
| *Corn.* | | | | | | | | | |
| From still | 77,000 | 7,000 | 44.0 | 651,600 | 59,200 | 372 | 33,300 | 3,030 | 19.0 |
| Over screen | 19,500 | 1,770 | 11.1 | 171,300 | 15,600 | 98 | 22,500 | 2,050 | 12.9 |
| Through screen | 57,500 | 5,230 | 32.9 | 480,300 | 43,700 | 274 | 10,800 | 980 | 6.2 |
| Pressed feed | | | | 39,000 | 3,500 | 22 | 19,500 | 1,770 | 11.1 |
| Slop from presses | 15,800 | 1,440 | 9.0 | 132,300 | 12,000 | 76 | 3,000 | 270 | 1.7 |
| For evaporation [a] | 37,500 | 3,410 | 21.4 | 313,900 | 28,500 | 179 | 7,100 | 650 | 4.1 |
| Evaporated slop | 2,600 | 290 | 1.5 | 28,400 | 2,600 | 16 | 7,100 | 650 | 4.1 |
| For first drier [b] | | | | 67,400 | 6,100 | 38 | 26,600 | 2,420 | 15.2 |
| For second drier | | | | 35,300 | 3,200 | 20 | 26,500 | 2,410 | 15.1 |
| Dried feed | | | | 29,000 | 2,600 | 17 | 26,300 | 2,390 | 15.0 |
| Distillate from evaporator | 34,900 | 3,170 | 20.0 | | | | None. | | |
| *Rye.* | | | | | | | | | |
| From still | 61,500 | 3,420 | 44.2 | 524,200 | 29,100 | 377 | 25,400 | 1,410 | 18.2 |
| Over screen | 13,900 | 770 | 10.0 | 124,200 | 6,900 | 89 | 16,400 | 910 | 11.8 |
| Through screen | 47,600 | 2,640 | 34.2 | 400,000 | 22,200 | 288 | 9,000 | 500 | 6.5 |
| Pressed feed | | | | 28,800 | 1,600 | 21 | 14,400 | 800 | 10.4 |
| Slop from presses | 11,400 | 630 | 8.2 | 95,400 | 5,300 | 68 | 2,000 | 110 | 1.4 |
| For evaporation [c] | 59,000 | 3,280 | 42.4 | 495,400 | 27,500 | 356 | 11,000 | 610 | 7.9 |
| Evaporated slop | 4,000 | 220 | 2.9 | 44,000 | 2,400 | 31 | 11,000 | 610 | 7.9 |
| For first drier [b] | | | | 72,800 | 4,000 | 52 | 25,400 | 1,410 | 18.2 |
| For second drier | | | | 33,800 | 1,880 | 24 | 25,300 | 1,400 | 18.2 |
| Dried feed | | | | 27,500 | 1,500 | 20 | 25,100 | 1,390 | 18.0 |
| Distillate from evaporator | 55,000 | 3,060 | 39.5 | | | | None. | | |

[a] Slop through screen, from presses, and waste A, less 35,800 gallons.
[b] Sum of pressed feed and evaporated slop.
[c] Slop through screen, from presses, and waste A.

As in the present system at Lynchburg, the thick slop from the screens should be filter-pressed to reduce the moisture content to about 50 per cent.

### COST OF PLANT.

From the foregoing statement regarding the processes involved it will be inferred that recovery by evaporation involves the installation of costly machinery and the erection of an extensive plant. Chief in the list of machinery is the evaporating apparatus. Manufacturers were consulted and estimates secured on three different machines, as follows:

No. 1. Capacity, 3,250 gallons per hour. Price, $21,555. Triple effect, cast iron with copper heating surfaces. Three and four-tenths pounds of steam required to evaporate 1 gallon. Space required, 16 feet by 48 feet by 26 feet in height.

No. 2. Capacity, 3,500 gallons per hour. Price, $31,850. Quadruple effect, cast iron with brass heating surfaces. Two and eight-tenths pounds of steam required to evaporate 1 gallon. Space required, 18 feet by 24 feet by 27 feet in height.

No. 3. Capacity, 4,150 gallons per hour. Price, $25,000. Quadruple effect, cast iron throughout. Two and eight-tenths pounds of steam required to evaporate 1 gallon.

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If we assume that 30 pounds of steam are equivalent to 1 horsepower hour, that 1 pound of coal will produce 7 pounds of steam, and that such coal can be procured for $2 per ton, the following data for the three machines are easily calculated from the figures in table 11:

TABLE 12.—*Cost of operating evaporators.*

| Number. | Corn. | | | Rye. | | | Horse-power capacity of boilers required. | Cost per season. |
|---|---|---|---|---|---|---|---|---|
| | Hours per day. | Pounds coal per day. | Cost per day. | Hours per day. | Pounds coal per day. | Cost per day. | | |
| 1 | 11— | 17,000 | $17.00 | 17— | 26,700 | $26.70 | 369 | $3,890 |
| 2 | 10— | 14,000 | 14.00 | 16— | 22,000 | 22.00 | 327 | 3,200 |
| 3 | 8+ | 14,000 | 14.80 | 13+ | 22,000 | 23.25 | 387 | 3,380 |

The average number of hours per day for corn distillation is 11, for rye distillation 18. Any one of these evaporators would therefore answer the purpose so far as time is concerned. In fact, there is little to choose between them. In about fifteen years the greater cost of operation on No. 1 would offset the greater first cost on No. 2, while in about seven years it would offset the greater first cost on No. 3. To state the comparison in another way, the additional capital invested in No. 2 will pay 7 per cent interest in decreased fuel bill, while the increased capital invested in No. 3 would similarly pay 15 per cent interest. In the daily cost of operating No. 3 is included 80 cents on corn and $1.25 on rye for lime to neutralize the acidity of the slop before passing it into a cast-iron machine.

Other considerations—such as floor space, labor, etc.—also enter into the problem. It is not the object of this paper to choose the best machine, and the foregoing discussion is merely intended to show that different types of evaporators manufactured by different firms will give results that are about equal viewed from an economic standpoint. In the estimates which are given later the foregoing have been averaged approximately, a theoretical machine costing $26,000 and operating at a daily cost of $15.50 for corn and $24 for rye being used as a basis of calculations.

Some additional expense would be incurred, including boilers of 400 horsepower capacity, costing about $2,000; a drier, $5,000; an addition to the slop house, $2,000, and installation, engineering, and incidentals not to exceed $5,000. These, it must be understood, are additions requisite to adapt the present plant to the manufacture of cattle feed by screening, filter-pressing, and drying, including the evaporation of thin slop previously wasted or fed to cattle in liquid form.

The estimated cost of present plant and additions is as follows:

TABLE 13.—*Estimated cost of food-stuff recovery plant at Lynchburg.*

| Old plant. | | Additions. | |
|---|---|---|---|
| Building | $2,000 | Building | $2,000 |
| Filter presses | 2,000 | Boilers | 2,000 |
| Drier | 6,000 | Drier | 5,000 |
| Miscellaneous | 2,000 | Evaporator | 26,000 |
| | | Miscellaneous | 5,000 |
| Total | 12,000 | Total | 40,000 |

The costs of the additions will apply to any distillery with a capacity of 1,750 bushels of corn or 1,392 bushels of rye per day. The total cost of installing a new plant throughout will be seen to be estimated at $52,000.

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### COST OF PROCESS.

The installation of an evaporating plant, with consequent increase in amount of feed grains, will increase the greater daily cost of production. Two firemen at $1.50 per day will be required for the additional boilers; two men, one at $2.50 and one at $1.50, will be required for the evaporator; two additional men at $1.50 will be required for pressing and drying; two additional men at $1.50 for sacking and loading. For rye one-half should be added to the above, except sacking and loading, because of the extra hours, or for the average daily cost during the season one and one-eighth times the above should be taken. Fuel costs will also be increased. In the following table the seasonal average costs per day and total costs per season are shown.

TABLE 14.—*Cost of present and proposed feed grains.*

| | Per day. | | | Per season. | | |
|---|---|---|---|---|---|---|
| | Proposed grain. | Present grain. | Increase. | Proposed grain. | Present grain. | Increase. |
| Labor: | | | | | | |
| Evaporation | $7.88 | ..... | $7.88 | $1,576 | ..... | $1,576 |
| Drying and pressing | 9.87 | $6.50 | 3.37 | 1,974 | $1,300 | 674 |
| Sacking and loading | 8.57 | 5.57 | 3.00 | 1,714 | 1,114 | 600 |
| Fuel: | | | | | | |
| Evaporation | 17.38 | ..... | 17.38 | 3,476 | ..... | 3,476 |
| Drying and pressing | 10.01 | 5.56 | 4.45 | 2,002 | 1,112 | 890 |
| Total | 53.71 | 17.63 | 36.08 | 10,742 | 3,526 | 7,216 |

### VALUE OF PRODUCTS.

The value of the product depends of course upon its quality. The present corn grains have an average value of $18.25 per ton, or $20.16 per ton of dry substance. This is very nearly at the rate of 2⅛ cents per pound of protein and fat, a ton of dry substance at that rate being worth $20.45. The present rye grains have an average value of $13.25 per ton, or $14.40 per ton of dry substance. At 2⅛ cents per pound of protein and fat the value would be $14.08 per ton of dry substance.

To find the comparative value of the grains obtained by evaporation three rye and three corn grains were prepared and sent to A. Lasché, Milwaukee, Wis., for analysis, a number of similar analyses made by Mr. Lasché being at hand for comparison. The results of these analyses appear in table 15.

Proposed rye grain No. 1 was obtained by evaporating the slop rye 1. It represents the total product which we would expect under the evaporation scheme. Proposed corn grain No. 3 is a similar product obtained by evaporating slop corn 1b. It is with these two grains that our estimates will be concerned.

The other proposed grains were prepared with a view to maintaining the present grains as they are and making separate grains of the product of the evaporator. In preparing proposed rye grain No. 2 thin rye slops were evaporated to a sirup, the excess moisture being taken up with finely chopped wheat straw in the ratio of 0.37 part of straw to 1 part of dry substance in slop. Proposed rye grain No. 3 is merely the fine material of No. 2 after passing through a sieve. Proposed corn grain No. 2 was prepared in the same manner as the similarly numbered rye grain, the ratio of straw to evaporated dry substance being 0.73 to 1. Proposed corn grain No. 1 was prepared by evaporating thin corn slops to a sirup, taking up the excess moisture with damp feed from the filter presses, and drying. The ratio of dry substance in sirup to dry substance in damp feed was 1 to 1. The values of these grains, as shown at the bottom of table 15, indicate that such a method of preparing grains is feasible and would be attended with profit.

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TABLE 15.—*Percentage composition of cattle-feed grains.*

| | Present rye grain, average of three analyses. | Proposed rye grain No. 1. | Proposed rye grain No. 2. | Proposed rye grain No. 3. | Present corn grain, average of seven analyses. | Proposed corn grain No. 1. | Proposed corn grain No. 2. | Proposed corn grain No. 3. |
|---|---|---|---|---|---|---|---|---|
| Moisture | 7.28 | 7.85 | 10.00 | 8.65 | 10.15 | 9.60 | 8.75 | 8.70 |
| Protein | 21.00 | 24.50 | 16.62 | 21.44 | 27.15 | 22.75 | 14.81 | 21.44 |
| Fat | 6.48 | 7.60 | 7.70 | 6.50 | 11.54 | 9.00 | 9.40 | 12.00 |
| Free extract | 8.11 | 36.55 | 45.38 | 38.75 | 8.10 | 36.60 | 38.75 | 26.92 |
| Starch | 6.24 | 19.10 | ..... | ..... | ..... | ..... | ..... | 25.44 |
| Fiber | 49.61 | ..... | 20.30 | 24.66 | 41.52 | 22.05 | 28.29 | ..... |
| Ash | 1.58 | [a] 4.40 | ..... | ..... | 1.57 | ..... | ..... | [a] 5.50 |
| Total | 100.30 | 100.00 | 100.00 | 100.00 | 100.03 | 100.00 | 100.00 | 100.00 |
| Protein and fat in dry substance | 29.64 | 34.83 | 27.02 | 30.57 | 43.06 | 35.11 | 26.53 | 40.93 |
| Value per ton of dry substance per lb. of protein and fat | $14.08 | $16.54 | $12.84 | $14.52 | $20.45 | $16.68 | $12.60 | $19.44 |

[a] Determined at laboratory of Ohio State board of health.

Returning to the value of the total product of grains obtained by the evaporation scheme, proposed rye grain No. 1 and proposed corn grain No. 3, we find that the rye has a much higher protein and fat content than the present rye grain. This is accounted for by the greater solubility of the proteids of rye. The same holds true of the free extract. It will be noted that ash, free extract, and fat have increased in amount in the new corn grain, while the protein has decreased. Rated at 2⅜ cents per pound of fat and protein, the new rye grain is worth $2.46 more per dry ton than the old, while new corn grain is worth $1.01 less per dry ton than the old. This does not, however, fully represent the true feed value of the new grains. Since the added part is almost all soluble, the digestibility of the new grains must be much higher than that of the old. As no data were available to determine the value of increased digestible nutritive material, the present rate paid for feed grains and the price of 2⅜ cents per pound of protein and fat were taken as the sole bases of value. Calculations based upon them are shown below.

TABLE 16.—*Amount and value of present and proposed feed grains.*

| | Dry tons per day. | | Value: Rye, $14.40; corn, $20.16 per ton. | | | | | Value: 2⅜ cents per pound protein and fat. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Per day. | | Per season. | | Total. | Per day. | | Per season. | | Total. |
| | Corn. | Rye. | Corn. | Rye. | Corn. | Rye. | | Corn. | Rye. | Corn. | Rye. | |
| Proposed grain | 13.15 | 12.55 | $265.10 | $180.72 | $39,765 | $9,036 | $48,801 | $255.64 | $207.58 | $38,346 | $10,379 | $48,725 |
| Present grain | 7.90 | 5.35 | 159.26 | 77.04 | 23,889 | 3,852 | 27,741 | 161.56 | 75.33 | 24,234 | 3,766 | 28,000 |
| Gain | 5.25 | 7.20 | 105.84 | 103.68 | 15,876 | 5,184 | 21,060 | 94.08 | 132.25 | 14,112 | 6,613 | 20,725 |

From the foregoing it will be observed that the gain in value is nearly the same whether calculated upon price of present grains or upon content of protein and fat, being 1.6 per cent less upon the latter basis.

As a secondary product of evaporation, on corn there will be 34,900 gallons and on rye 55,000 gallons of distillate, which may be utilized at the cost of condensing the vapor from the slop. Tests made by G. L. Bering at Lynchburg showed that this distillate will convert starch into dextrose ten minutes quicker than the best water now available at the distillery. It can be used in the mashing and cooking process, therefore, to excellent

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advantage, and it will be more than sufficient in quantity to answer this purpose. Under the multiple system of evaporation this product will be exhaust water and steam and will doubtless be suitable to discharge into the cookers without condensation. This is an asset that can not well be calculated in money value, but is well worthy of consideration as an economy resulting from the evaporation process.

### PROFITS.

Having obtained approximate figures upon the cost of plant, cost of operation, and value of product, we are in a position to consider both amount and per cent of profits obtainable from the proposed methods of slop treatment.

From tables 14 and 16 the following is deduced:

TABLE 17.—*Seasonal value, cost, and profit for present and proposed feed grains.*

| | Value based on price of present grains. | | | Value based on protein and fat content. | | |
|---|---|---|---|---|---|---|
| | Value. | Cost. | Profit. | Value. | Cost. | Profit. |
| Proposed grain | $48,801 | $10,742 | $38,059 | $48,725 | $10,742 | $37,983 |
| Present grain | 27,741 | 3,526 | 24,215 | 28,000 | 3,526 | 24,474 |
| Increase | 21,060 | 7,216 | 13,844 | 20,725 | 7,216 | 13,509 |

A profit of approximately $38,000 per season is therefore obtainable upon an investment of $52,000 in a complete plant, including evaporation. This represents a return of 73 per cent per annum. An increased profit of about $13,600 is obtained by adding a $40,000 plant for evaporation to the old plant, as described; this is at the rate of 34 per cent per annum. It must be remembered, also, that the foregoing estimates are based upon figures showing less than the true food value of the grains. A practical test demonstrating their greater nutritive properties should result in higher prices and increased profits. Furthermore, a considerable margin of safety is afforded by the calculation of the chief cost (fuel for evaporation) at 7 pounds of steam from 1 pound of coal. One pound of good coal should, in practice, produce between 8 and 9 pounds of steam.

The following tables show the value, cost, and profit per ton of dried product (9½ per cent for corn grains and 8 per cent for rye grains being assumed moisture content), and the value, cost, and profit per bushel of grain mashed. It will be observed that while the profit per ton is decreased 12 or 15 per cent the profit per bushel of grain mashed is increased 55 per cent because of the greater volume of the product.

TABLE 18.—*Value, cost, and profit per ton of feed-grain product.*

| | Value based on price of present grains. | | | Value based on protein and fat content. | | |
|---|---|---|---|---|---|---|
| | Value. | Cost. | Profit. | Value. | Cost. | Profit. |
| Proposed grain | $17.04 | $3.81 | $13.23 | $16.85 | $3.81 | $13.04 |
| Present grain | 17.34 | 2.20 | 15.14 | 17.50 | 2.20 | 15.30 |
| Increase | ..... | 1.61 | ..... | ..... | 1.61 | ..... |
| Decrease | 0.30 | ..... | 1.91 | .65 | ..... | 2.26 |

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TABLE 19.—*Value, cost, and profit in cents per bushel of grain mashed.*

| | Value based on price of present grains. | | | Value based on protein and fat content. | | |
|---|---|---|---|---|---|---|
| | Value. | Cost. | Profit. | Value. | Cost. | Profit. |
| Proposed grain | 14.5 | 3.2 | 11.3 | 14.5 | 3.2 | 11.3 |
| Present grain | 8.4 | 1.1 | 7.3 | 8.4 | 1.1 | 7.3 |
| Increase | 6.1 | 2.1 | 4.0 | 6.1 | 2.1 | 4.0 |

Table 17 shows that the cost of production is only two-ninths the value of the product under the proposed method of disposal. This method could obviously be applied, therefore, to a distillery two-ninths as large (capacity abc t 400 bushels of grain per day) with a very considerable degree of profit. In fact, there does not seem to be a minimum limit to the size of the distillery to which it could be economically applied, except the limit for economic operation of a multiple evaporator.

### RESULT AT LYNCHBURG DISTILLERY.

A plant for the evaporation of slop was installed at the Lynchburg distillery late in the autumn of 1905. This plant was inspected by the writer while it was in process of construction, early in December, 1905, and again when in operation, on March 8 and May 1, 1906.

The slop is first passed over a brass screen containing 576 perforations to the square inch. This screen has an area of 21 square feet and a slope of about 9 inches in a length of 2 feet 8 inches. The slop passing over this screen is conducted to a second screen of similar area and somewhat greater slope.

The thick slop from the second screen is received in a wooden vat and pumped thence to be filtered in two 40-plate presses. Each press is 20 feet in length and 3 feet in diameter and has a net filtering area of 230 square feet.

The thin slop from both screens is received in large wooden tanks, from which it is pumped to the evaporator.

The evaporating apparatus is of chief importance and will therefore be described in some detail. The machine used is the Hoffman-Ahlers triple-effect vacuum evaporator, a view of which is shown in fig. 5. Each effect consists, essentially, of two chambers, $A$ and $B$, $A'$ and $B'$, $A''$ and $B''$, connected by four large pipes, $C$, $C'$, and $C'''$, and also by a great number of tubes, placed within the steam chamber, $E$, $E'$, and $E''$. The slop is introduced at $F$, into one of the pipes, $C$, of the first effect, and by the internal conditions is forced to circulate through the tubes (not visible in the cut) in the steam chamber $E$. These tubes are heated by steam under pressure, and the slop in passing through them is largely vaporized. The vapor passes out at the top of chamber $A$, through the large pipe $G$, which leads to the chamber $E'$ of the second effect. The concentrated slop passes out at $H$, enters the second effect at $F$, and is further concentrated at a reduced pressure in the tubes $D'$. The vapor from the second effect is carried by the pipe $G'$ to the steam chamber $E''$ of the third effect. The concentrated slop enters the third effect through one of the pipes $C'''$ and is still further concentrated under a greatly reduced pressure. The vapor from the third effect is exhausted through the pipe $G''$, by the vacuum pump $K$, which serves to reduce the pressures as desired in the successive effects. The concentrated sirup from the third effect is pumped away to a convenient place by the magma pump $L$.

After several months of experimentation this apparatus is now in good working order. It is capable of treating more than 40,000 gallons of the thin slop in twenty hours (guaranteed capacity 2,700 gallons per hour) and reducing it 88 to 90 per cent in volume. It is now operated with 40 pounds of steam pressure in the first effect, a 3 or 4 inch vacuum in the second effect, and a 26-inch vacuum in the third effect. This apparatus costs, in place, $16,000. While this machine will dispose of all the waste corn slop at Lynchburg,

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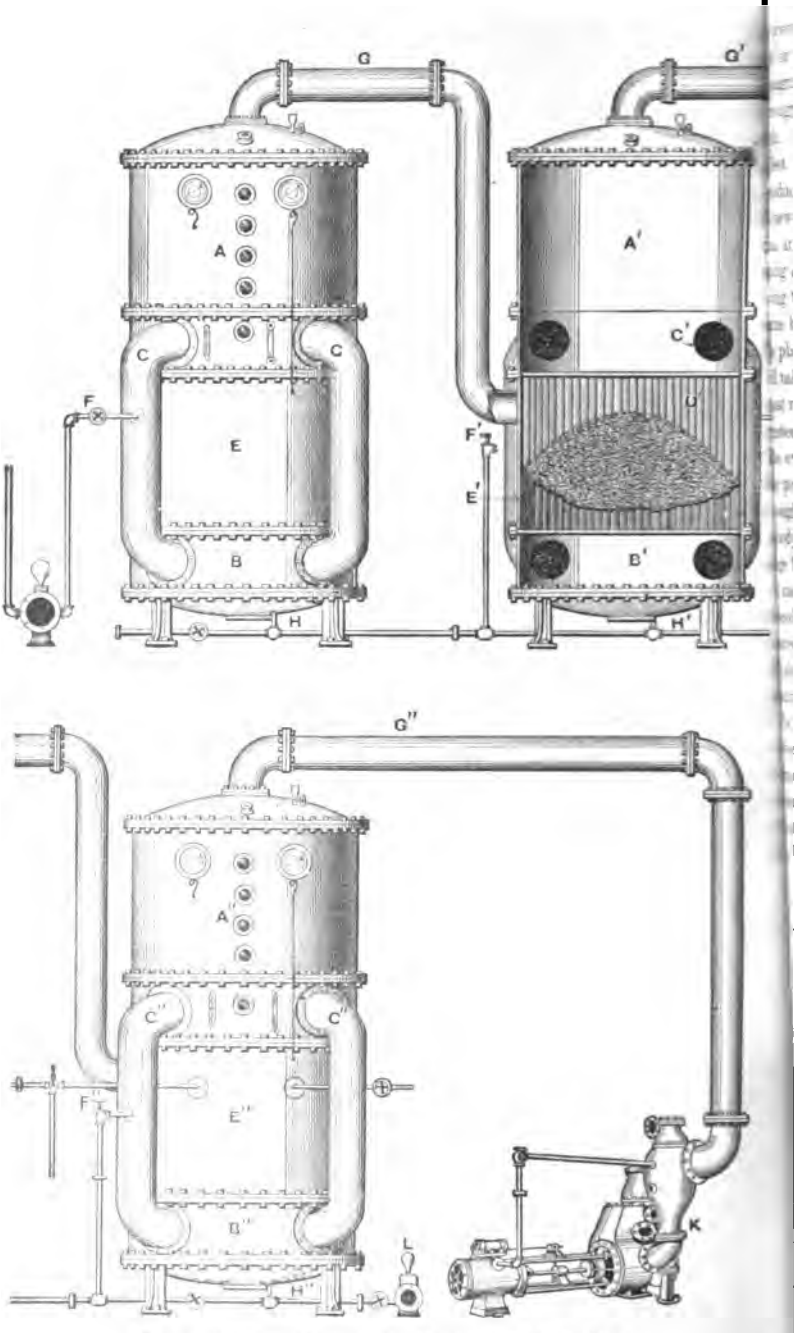


FIG. 5.—Hoffmann-Ahlers triple-effect vacuum evaporator.

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ay prove too small to evaporate all the rye slop. A small vacuum pan has been lled for further slop reduction when desired.

e magma from the evaporator is added to the feed from the filter presses, and the two horoughly mixed by passing through a screw conveyor 1 foot in diameter and 40 feet rgth. It is then dried by passing through a direct-heat rotary drier, 40 feet in length 5 feet in diameter, and a steam rotary drier, 20 feet in length and 6 feet in diameter. product of these machines is placed in sacks for shipment.

ie new apparatus consists of screens; evaporator and vacuum pan with accessory liquor, ma, and vacuum pumps; steam drier; addition to building; and a considerable amount ping and a few minor pieces of apparatus.

wing to difficulty experienced in the use of the new steam drier with the moist feed a hine has been specially designed to replace it.

he plant is so constructed that almost unlimited variations in operation can be secured. ill take a considerable length of time to develop the most economical plan of operation, ust necessarily be the case in any pioneer plant. Many possible economies have already ested themselves, and others may be expected to develop with longer operation.

he evaporation system as installed at Lynchburg is an unqualified success, and even ler present imperfect conditions a substantial profit upon the investment is being made. hough it is too early to figure definite profits, the indications are that the estimates in body of this report will be realized and probably exceeded. In making these estimates rge factor of safety was used and the cost of plant and operation were purposely placed a maximum figure. The installation at Lynchburg proves that the cost figures can be luced in the main by about 25 per cent. The predicted increase in amount of manu-tured food stuff has not yet been realized because all the slop has not been evaporated. ie plant installed is apparently too small to evaporate all the slop at all times, but greater ounts will be handled when the mode of operation is perfected.

The predicted change in quality of manufactured feed has been realized. The new feed sweeter and has a more attractive odor. It has a higher specific gravity. According to emical analysis the protein and fat content for corn and the fat content for rye are slightly creased, but this decrease is more than made up by the increased digestibility of these and ie other constituents. Analyses of concentrated slop liquors made by A. Lasché, Milwau-ee, Wis., are shown below.

TABLE 20.—*Analyses of concentrated rye and corn slop.*

| | Rye. | | Corn. | |
|---|---|---|---|---|
| | Per cent. | Per cent in dry substance. | Per cent. | Per cent in dry substance. |
| Moisture | 86.40 | ..... | 75.31 | ..... |
| Protein | 3.025 | 22.17 | 6.497 | 26.32 |
| Fat | .63 | 4.63 | 2.2 | 8.91 |
| Free extract | 8.7 | 63.95 | 13.6 | 55.08 |
| Starch | .3 | 2.20 | .8 | 3.2 |
| Ash | .883 | 6.49 | .293 | 1.22 |
| Crude fiber | .062 | .56 | 1.3 | 5.27 |
| Total | 100.000 | 100.00 | 100.000 | 100.00 |

The great per cent of moisture in the rye sample is to be accounted for by the fact that the evaporator had just been placed in operation. The 75 per cent moisture content of the corn sirup corresponds exactly with the predicted value, but it seems probable that both rye and corn sirups can profitably be concentrated in the evaporator to contain about 70 per cent of moisture. By comparing table 20 with table 15, it will be seen that the chief



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result in quality obtained by adding this sirup to the old grains is a large increase in free extract, a lesser increase in ash, and decrease in starch and crude fiber. The new grains will make the better cattle food.

With regard to stream pollution little can be said at present. Of course stream pollution can be entirely prevented by evaporating all the slop. The new plant at Lynchburg is not at present evaporating all the slop all the time, so that stream pollution still continues. By the end of the present distilling season better conditions will undoubtedly prevail, and probably all pollution will be obviated. The difficulties incident to the perfection of any entirely new system of manufacture are the cause of the present continuance of pollution.

## SUMMARY.

The results of the investigation may be summed up as follows:

1. From the still and rectifier of a distillery about 45 gallons of waste slop liquor are discharged for each bushel of grain mashed. This liquor contains approximately 5 per cent (by weight) of solid matter, nearly half of which is held in solution. All the elementary compounds of the grain are represented in full quantity, starch excepted, the greater part of this substance being separated in the manufacture of the spirituous product.

2. One part of distillery refuse discharged into a stream of moderate fall having an average flow of 150 parts of water will produce a serious pollution for a long distance below the point of its introduction and may at times render the stream waters unfit for any use.

3. By screening out most of the suspended solids, nearly 10 per cent (by volume) of the slop may be converted into a dry cattle feed at a high rate of profit; an additional 50 per cent may be utilized as a liquid cattle food, generally with a slight profit; in the manufacture of some liquors a considerable quantity may be used instead of water in certain processes. From 10 to 40 per cent can not be profitably used and is run to waste.

4. Stream pollution by such refuse may be wholly avoided by means of evaporation recovery of cattle feed grains from the slops. By this method of disposal the entire slop product of a distillery may be utilized, the solid matter as a feed stuff and the distillate from evaporation as water for mashing.

5. As applied to a distillery using daily 1,750 bushels of corn for a season of 150 days and 1,392 bushels of rye for a season of 50 days, the following data regarding the process may be accepted as approximate:

*a*. Cost of complete recovery plant ..... $52,000
*b*. Annual profit over operating expenses on investment in complete plant for evaporation recovery, per cent ..... 73
*c*. Cost of additional plant to add evaporation to recovery by screening ..... $40,000
*d*. Annual profit over operating expenses afforded by increased product, based on investment in additional plant to add evaporation to recovery by screening, per cent ..... 54

6. A practical trial of the evaporation method at Lynchburg, Ohio, substantiates all the claims made for it and indicates that it will prove to be a rather greater source of profit than had been expected.

7. This system of economical disposal of slops can probably be applied successfully to any distillery large enough to create a serious nuisance by the discharge of its waste liquors into any but the smallest of streams.

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WS 179. Prevention of stream pollution by distillery refuse, based on investigations at Lynchburg, Ohio, by Herman Stabler. 1906. 34 pp., 1 pl.

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Water-Supply and Irrigation Paper No. 180 Series M, General Hydrographic Investigations, 18

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

# TURBINE WATER-WHEEL TESTS

AND

# POWER TABLES

BY

ROBERT E. HORTON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1906

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# CONTENTS.


| | Page. |
|---|---|
| Introduction | 7 |
| Principal types of water wheels | 7 |
| Vertical water wheels | 8 |
| Classes of turbines | 9 |
| Tangential outward flow turbines—Barker's mill | 9 |
| Radial outward-flow turbines—the Fourneyron turbine | 9 |
| Parallel downward-flow turbine—the Jonval turbine | 12 |
| Radial inward-flow turbines—the Francis turbine | 13 |
| Mixed-flow turbines | 13 |
| Scroll central-discharge wheels | 14 |
| American type of turbines | 14 |
| Types of turbine gates and guides | 16 |
| Mechanical principles of the turbine | 17 |
| Horsepower and efficiency of turbines | 19 |
| Turbine testing | 22 |
| General review | 22 |
| Centennial tests | 24 |
| Tests by James Emerson, and the Holyoke hydrodynamic experiments | 30 |
| Tests by Holyoke Water Power Company | 36 |
| General discussion | 36 |
| Detailed tests | 41 |
| McCormick turbines | 41 |
| Hercules turbines | 60 |
| Samson turbines | 66 |
| New American and Swain turbines | 71 |
| The use of the turbine as a water meter | 76 |
| Reliability of Holyoke tests as to turbine discharge | 77 |
| Variation in discharge for different wheels of same pattern | 78 |
| Variation in discharge for different wheels of the same type | 79 |
| Variation of turbine discharge with speed | 80 |
| Variation of turbine coefficients with variation in head | 81 |
| Methods of turbine setting and arrangement | 82 |
| Turbine plants for varying head | 85 |
| Conditions governing economy in size and number of turbines used | 85 |
| Manufacturer's tables of power, speed, and discharge | 87 |
| General discussion | 87 |
| Rating table for Fourneyron turbines | 94 |
| McElwain | 94 |
| Rating tables for scroll central-discharge turbines | 95 |
| John Tyler | 95 |
| Reynolds | 95 |
| Carley helical | 96 |
| Perfection | 96 |
| Jones Little Giant | 97 |




Digitized by Google

Manufacturer's tables of power, speed, and discharge—Continued. Page
General discussion—Continued.
Rating tables for Jonval turbines ... 98
McElwain ... 98
Bloomingdale, or Wait's Champion ... 98
Dix ... 99
Osgood ... 99
Bodine ... 99
Chase ... 100
Rating tables for register-gate turbines ... 101
Gates Curtis ... 101
Eclipse double ... 101
Helmer's patent Rome ... 101
Case National ... 102
Wetmore ... 102
Flenniken ... 103
Humphrey standard IXL ... 103
Humphrey standard XLCR ... 104
Burnham's new improved ... 104
Balanced gate ... 105
Alcott's high duty ... 105
Lesner's improved ... 106
Risdon ... 107
Rating tables for pivot-gate turbines ... 108
Crocker ... 108
Camden horizontal ... 108
Camden vertical ... 109
Camden steel double ... 109
United States ... 109
Cole Dominion ... 110
Bradway ... 110
Bartley water-tight ... 111
Canada ... 111
Elmer ... 112
Eureka ... 112
Smith improved Success ... 113
Smith new Success ... 114
American ... 114
New American ... 115
Poole & Hunt Leffel ... 116
Trump model ... 117
Leffel ... 117
Leffel Samson ... 119
Rating tables for cylinder-gate turbines ... 119
Rochester ... 119
Swain ... 120
Dolan's Little Giant ... 120
Dolan's Improved Little Giant ... 121
Hunt Standard, new pattern ... 122
Hercules ... 122
McCormick ... 123
McCormick's New England ... 123
Taylor sleeve-gate ... 124
Victor ... 124
Victor high-pressure ... 125

Digitized by Google

Page.
Literature ..... 126
Historical ..... 126
Descriptive ..... 126
Vertical water wheels ..... 127
Turbines ..... 127
Turbine design ..... 127
American type of turbine ..... 128
Mathematical theory of turbines ..... 128
Turbine governing ..... 129
Impulse water wheels ..... 130
Index ..... 131

Digitized by Google

# ILLUSTRATIONS.


| | | Page. |
|---|---|---|
| PLATE | I. *A*, Recent American type of water-wheel runner; *B*, Dynamometer, Holyoke testing flume | 14 |
| | II. *A*, Turbines on horizontal shaft; *B*, Pair of turbines on horizontal shaft | 82 |
| FIG. | 1. Section of Fourneyron turbine | 10 |
| | 2. Plan of Fourneyron turbine | 10 |
| | 3. Double Fourneyron turbine at Niagara Falls | 11 |
| | 4. Section of guides and buckets, Niagara Fourneyron turbine | 12 |
| | 5. Section of Francis center-vent turbine | 13 |
| | 6. Section of runner of Francis center-vent turbine | 13 |
| | 7. Schiele turbine | 14 |
| | 8. Cross section of early turbine with deep bulging buckets, pivot gates, and an adjustable step bearing | 14 |
| | 9. Diagram illustrating principle of reaction | 17 |
| | 10. Diagram showing impulse against curved vanes | 18 |
| | 11. Diagram illustrating theory of moving vanes | 18 |
| | 12. Diagram showing interference and eddies in a turbine | 22 |
| | 13. Diagram showing efficiency of various prime movers | 23 |
| | 14. Cross section of Holyoke testing flume | 37 |
| | 15. Log of test of 36-inch Hercules turbine, full gate | 38 |
| | 16. Log of test of 36-inch Hercules turbine, 0.806 gate | 39 |
| | 17. Log of test of 36-inch Hercules turbine, 0.647 gate | 39 |
| | 18. Log of test of 36-inch Hercules turbine, 0.488 gate | 40 |
| | 19. Log of test of 36-inch Hercules turbine, 0.379 gate | 40 |
| | 20. Proportional discharge coefficients, 12-, 15-, 18-, and 21-inch McCormick turbines | 41 |
| | 21. Proportional discharge coefficients, 24-, 27-, 30-, and 33-inch McCormick turbines | 42 |
| | 22. Proportional discharge coefficients, 36-, 38-, 42-, and 45-inch McCormick turbines | 42 |
| | 23. Proportional discharge coefficients, 48-, 51-, 54-, and 57-inch McCormick turbines | 42 |
| | 24. Proportional discharge coefficients, Hercules turbines | 60 |
| | 25. Proportional discharge coefficients, Leffel-Samson turbines | 66 |
| | 26. Efficiency curves, Leffel-Samson turbines | 67 |
| | 27. Proportional discharge coefficients, New American turbines | 71 |
| | 28. Part-gate discharge coefficients for three 24-inch Hercules turbines | 78 |
| | 29. Types of part-gate discharge coefficient curves | 79 |
| | 30. Variation of turbine discharge with speed, 24-inch McCormick turbine | 81 |
| | 31. Variation of turbine discharge with speed, 42-inch McCormick turbine | 82 |
| | 32. Variation of turbine discharge with speed, 54-inch McCormick turbine | 83 |
| | 33. Cross section of power house near Geneva, Switzerland | 84 |




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# TURBINE WATER-WHEEL TESTS AND POWER TABLES.

By Robert E. Horton.

## INTRODUCTION.

This paper is not intended as a treatise on the turbine, and comprises no extensive discussion of its theory, design, or construction. It is mainly a compilation of data derived from tests and from manufacturers' power tables of American stock sizes of turbines. A bibliography has been added, giving selected references for the use of those who may wish to investigate the subject further.

The primary object of the paper has been to furnish information required in the work of the Geological Survey, where the turbine is used as a water meter in gaging streams. A secondary object has been to furnish information from which the power developed at mills can be determined from the sizes and types of water wheels used. Such information is often required in the census and other water-power canvasses. The water rights of mills can often be definitely determined only from the quantity of water used by the turbines which are or have been employed to develop the power. Some of these turbines are no longer built or catalogued, and it is believed that the manufacturers' rating tables and the record of tests of the older types of wheels will be serviceable to engineers who may be required to determine questions of water rights.

Many antiquated patterns of turbines are still on the market, and a clear presentation of the evolution of the different types of turbine water wheels should be of practical service to those who wish to know the merits and demerits of the various styles. Much of the data has been presented in graphic form. It is believed that the section treating of the selection and arrangement of turbines in power plants will be of service to all turbine users.

## PRINCIPAL TYPES OF WATER WHEELS.

A water wheel may be defined as a machine that derives mechanical power from the energy imparted to falling water by gravity. Numerous modes of classification of water wheels have been used. They may be classified as follows:

(1) According to position of the plane of the wheel—whether vertical or horizontal.

(2) According to the mode of action of the water—whether by simple gravity, by pressure under head (as against a piston), by impulse or kinetic energy of a spouting jet, by reaction (illustrated by the pressure against the side of a containing vessel opposite a spouting jet), or by combined pressure and reaction.

(3) According to direction of the flow of water with reference to the axis of the wheel or to the plane of the wheel—whether tangential to the wheel, radially inward, radially outward, parallel to the axis, or a combination of two or more of these.

(4) By type—as overshot, breast, undershot, flutter, tub, Jonval, Fourneyron, Vortex, and American.

(5) As vertical water wheels, turbines, and impulse wheels. These three classes may readily be subdivided to include all the types of water wheels that have been named above.

All water wheels of the older types, including overshot, breast, Poncelet, and undershot wheels, were placed on horizontal shafts. Turbines and their prototypes, the tub wheel



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and the rouet volante, were placed on vertical shafts. The classification by position of shaft thus served very well to distinguish between water wheels and turbines until turbines were placed on horizontal shafts. The rouet volante or flutter wheel of the ancients consisted of flat, vertical vanes projecting radially from a vertical wooden shaft. The water jet from the feeding spout struck the vanes tangentially near their ends. Such wheels have been used for centuries in India, Egypt, Syria, and southern France. An excellent example of a rouet volante was in use until recently in a plaster mill in western New York. The rouet volante placed on a horizontal shaft becomes essentially the hurdy-gurdy of the early western miners. It may thus be considered as the prototype of the modern impulse water wheel as well as of the turbine.

Much uncertainty of meaning has arisen from the conflicting use of terms in classifying water wheels. The terms impulse and reaction, for example, have been used by different authors with opposite meanings. The conception of reaction is somewhat difficult to grasp, and as the definition of this word seems uncertain its use is to be discouraged. Its usual meaning will be explained, however, in the course of this paper, in order that its use in works of reference may be understood.

## VERTICAL WATER WHEELS.

The overshot wheel is a characteristic type, although it is probably antedated historically by the bamboo varia, which was used by the Chinese, as they claim, as early as 1000 B. C. A form of inverted chain pump has been used in the Orient from time immemorial for lifting water from streams to irrigation ditches. A motor of this type has recently been patented in America, and one is in operation in Mannsville, N. Y., under a head of 23 feet, yielding abundant power to drive a grist and planing mill. Such wheels, as well as overshot wheels, operate purely by gravity, and yield theoretically a very high efficiency. The objections to this type of motor are cumbersomeness, waste of water by leakage and spilling from the buckets, inability to operate in backwater, and obstruction by ice in winter.

Overshot wheels were formerly built of great size. One at Laxey, Isle of Man, constructed about forty years ago and said to be still in operation, is 72 feet 6 inches in diameter and develops about 150 horsepower.[a] A number of overshot wheels are in use at old mills in the Catskill Mountains in New York. A firm in Pennsylvania manufactures "steel overshot" water wheels, which, it is claimed, have a high efficiency.

Breast wheels are operated partly by gravity and partly by kinetic energy, the water from the feeding chutes striking the floats or vanes of the wheel.

Undershot water wheels and current wheels operate entirely by the kinetic energy of the moving water.

Tide wheels and undershot wheels usually require a floating framework or other device to raise and lower them with fluctuation in water level.

Breast and undershot wheels never attain high efficiency, and in addition are subject to all the objections of the overshot water wheel. The labors of James Smeaton, Fairbarn, and the ingenious Poncelet, who substituted epicycloidal-curved vanes for straight buckets in wheels of these types, increased their efficiency somewhat, but such wheels were quickly superseded by the parallel-flow turbine of Jonval and the Boyden-Fourneyron turbines upon their introduction into this country. Vertical water wheels are still considerably used in Germany.

The theory of water wheels has been elaborately developed and their literature is much more profuse than that of turbines.[b]

[a] See catalogue of the Pelton Water Wheel Company for 1898, pp. 70–71.
[b] See bibliography on pages 126–130.

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### CLASSES OF TURBINES.

A turbine[a] may be defined as a water wheel in which the water is admitted to all the vanes or buckets simultaneously. It is thus distinguished from vertical water wheels, which receive the water at the top or one side only, and from impulse water wheels, which receive a spouting jet or jets from nozzles directed tangentially against the perimeter of the wheel.

The component parts of a turbine are the "runner," the "case," the "gate" or "gates," and the "guides." Commonly the gates and guides are included in the "case." The runner is that portion of the turbine which revolves. It comprises the vanes, the crown plate, partition plates or rim bands, which cover, subdivide, or strengthen the vanes, and the power shaft. The term "bucket" is applied to the passage for the water in the runner. The vanes or floats are the partitions separating the buckets and forming the runner. The term "buckets" is also often used to signify the vanes. The chutes are the openings through which the water passes into the wheel, and the guides are the partitions separating the chutes The gates serve to shut off and regulate the supply.

The flow of water through a turbine may be directed either radially inward or outward or parallel to the axis, or inward and parallel, or inward, parallel, and outward. The representative types of these several classes are as follows:

Tangential flow: Barker's mill.

Parallel flow: Jonval turbine.

Radial outward flow: Fourneyron turbine.

Radial inward flow: Thompson vortex turbine; Francis turbine.

Inward and downward flow: Central discharge scroll wheels and earlier American type of wheels; Swain turbine.

Inward, downward, and outward flow: The American type of turbine.

### TANGENTIAL OUTWARD-FLOW TURBINES—BARKER'S MILL.

In impulse water wheels the jet strikes or enters the buckets in a direction tangential to the circumference of the runner. In most forms of turbines the water flows outward, inward, or downward through the buckets, leaving them tangentially or nearly so.

The simplest type of tangential outflow is Barker's mill, invented in 1740. This wheel has radial arms and operates purely by reaction. Such wheels are still used on the Morris Canal in New Jersey for drawing barges up the inclined planes which serve in place of locks. The wheels have four arms of 6 feet radius, with openings at the ends 3½ inches wide by 15½ inches high.[b]

James Whitelaw, of Paisley, developed Barker's mill, which has spiral tapering arms so curved that water flows radially when the mill is running at proper speed. A wheel of this type erected on Chard Canal, 1842, for purposes of hauling boats up inclines developed 75 per cent efficiency on 25 feet fall. Owing to their large size, low speed, and inability to operate in backwater such wheels have never come into extensive use.

### RADIAL OUTWARD-FLOW TURBINES—THE FOURNEYRON TURBINE.

A primitive type of water wheel, which comes under the class of turbines proper, is that of Cadiat. This is an outward-discharge turbine without guide chutes, and therefore it may be said to belong to the same stage in turbine evolution as do the tub and scroll central-discharge wheels, although the form of runner and the direction of flow are similar to those of the Fourneyron turbine. The weight of the runner is carried by a step-bearing at the lower end of the shaft. The discharge is regulated by an outside cylinder gate, probably the first one used. The buckets are curved in a vertical plane.

Fig. 1 shows a sketch in section of an early Fourneyron turbine (after Morin). The guide chamber *C* received the vertical pressure of water, and was suspended from above by means

[a] From Latin *turbo*, to revolve. The etymology of the word does not sufficiently distinguish the class.

[b] Wilson, H. M., The Morris Canal and its inclined planes: Scientific American Supplement, February 24, 1883

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of a hollow column surrounding the driving shaft. The discharge was regulated by a cylinder gate *G* between the guide *C* and the bucket *V*. Slits in the gate ring *G* opposite the end of each guide enabled the guides to be extended outward nearly to the vanes.

Fig. 2 shows a plan of the guide chamber and runner of this turbine. The vanes or buckets have a radial direction at their inner ends, where they receive the water. Under the mechanical conditions established the water enters the wheel with a tangential velocity

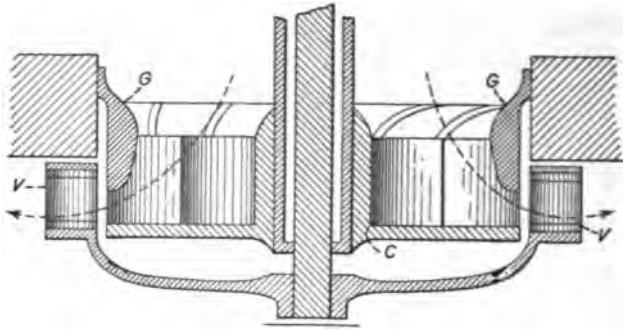


FIG. 1.—Section of the Fourneyron turbine.

equal to the velocity of the bucket, is carried outward by the radial component of its velocity, and in passing outward is deflected by the backward-curved vanes or buckets, thus doing work. Inasmuch as the tangential component of the velocity equals that of the buckets the water could do no work by impulse, hence the Fourneyron turbine is purely a pressure or reaction turbine.

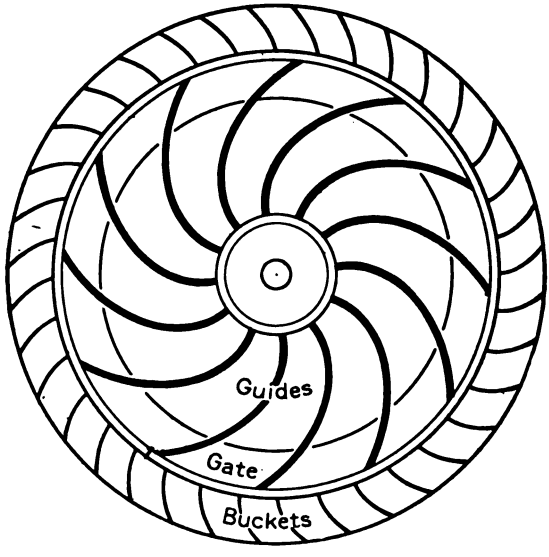


FIG. 2. – Plan of the Fourneyron turbine.

The excellence of its mechanical construction, its high efficiency, its ability to work under very great heads, and its ability to operate in backwater with good efficiency rendered the appearance of the Fourneyron turbine a notable event in the history of water power. The experiments of M. Fourneyron were begun in 1823, and his first turbine was erected at Pont sur l'Ognon, France, in 1827. It was followed by several others, operating under various heads up to 144 feet, which yielded efficiencies as high as 80 per cent.

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In 1837 M. Fourneyron erected a turbine at St. Blaise, Switzerland, which operated under a head of 354 feet. The diameter of the wheel was 13 inches. The depth of the buckets was slightly less than one-fourth of an inch. This wheel made from 2,200 to 2,300 revolutions per minute, and is reported to have yielded an efficiency of 80 to 85 per cent. The water was conducted to the turbine through a cast-iron pipe conduit, and to prevent the choking of the minute apertures in the water wheel the supply was filtered before use.

January 1, 1843, a Fourneyron turbine, designed by Elwood Morris, who had translated the valuable experiments of Morin into English, was erected at Rockland Cotton Mills, on the Brandywine. This turbine was tested by Morris in the fall of 1843, together with a second one, located at Dupont Powder Mill, also on the Brandywine, near Wilmington, Del. These turbines gave maximum efficiencies of 70 to 75 per cent, respectively.

In 1844 a Fourneyron turbine, constructed by Uriah A. Boyden, was erected at the Appleton Company's cotton mills in Lowell, Mass. Carefully conducted tests showed that this turbine yielded an efficiency of 78 per cent. The Appleton turbine was rapidly followed by others of Boyden's design, which soon became the standard in New England, displacing the old wooden vertical wheels. The Boyden turbines were expensive, cumbersome, and gave low efficiency when operated at part gate, and "owing to the large number of buckets with small apertures they were liable to become choked by chips, leaves, and other floating obstructions, not to speak of fish. At Fall River, Mass., the first turbines are said to have been stopped by eels on their annual migrations to the sea."[a]

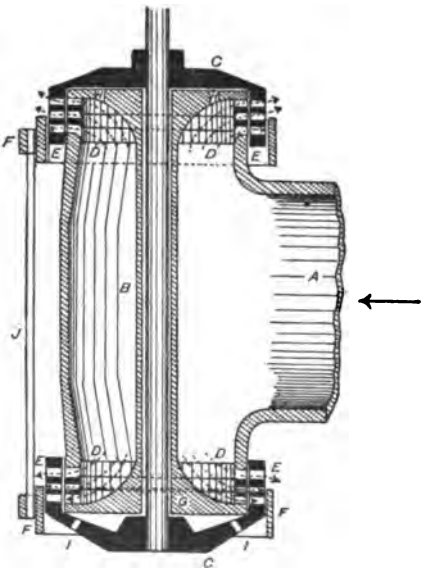


FIG. 3.—Section of penstock and runners of double Fourneyron turbine at Niagara Falls. *A*, Flume; *B*, penstock; *CC*, runners; *DD*, guides; *EE*, buckets; *FF*, gate rings; *HH*, holes in upper drum; *II*, holes in lower runner; *J*, gate stems.

The manufacture of Fourneyron turbines was taken up by a number of machine works, and several of the Boyden turbines are still in use in New England. As usually constructed this turbine has a cast-iron casing attached to one side of the flume, similar to the scroll central-discharge wheel.

The ability of a turbine of the Fourneyron type to work efficiently under very high heads was shown by the experiments made at St. Blaise. The manufacture of turbines of the Fourneyron type has been revived in recent years, owing to the demand for turbines to operate under very high heads, as at Niagara Falls and elsewhere.

Figure 3 shows a schematic cross section of the double Fourneyron turbine used in the first installation of the Niagara Falls Power Company. This was operated under a head of about 135 feet. The turbine is mounted in a globe penstock, similar to that used in early New England practice, with the exception that two wheels are used, one being placed at the top and the other at the bottom of the penstock. As shown in fig. 3 the runner *C* and buckets *E*, which are represented in black, are attached to the vertical shaft. The guides *D* and buckets *E* are subdivided into three compartments by partition plates. The discharge is regulated by outside cylinder gates *F*. The gate rings for the upper and lower wheels are connected by rods, one of which is shown at *J*. The gate rings *F* are raised and lowered in unison to shut off the outflow from or to open, one after another, the horizontal compartments, as required. The cylindrical penstock is shown in section by hachure. The disk or

[a] Webber, The Development of Water Power.

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drum forming the lower end of the penstock is made solid, and holes *II* are provided in the lower runner to allow any water which may enter between the lower drum *G* and the lower runner through the clearance spaces to pass out. Holes *HH* are provided in the upper penstock drum to allow water under full pressure of the head to pass through and act vertically against the upper runner *C*. In this way the vertical pressure of the great column of water is neutralized and a means is provided to counterbalance the weight of the long vertical shaft and the armature of the dynamo at its upper end. These turbines discharge 430 second-feet, make 250 revolutions per minute, and are rated at 5,000 horsepower. A section of one of the guide rings and runners is shown in fig. 4. The guides and buckets are of bronze, and their surface curves form arcs of circles of varying radii. Except for the central thickening of the vanes, the forms of the chutes and buckets do not differ materially from those of the same parts of the early turbines of Boyden and Fourneyron.

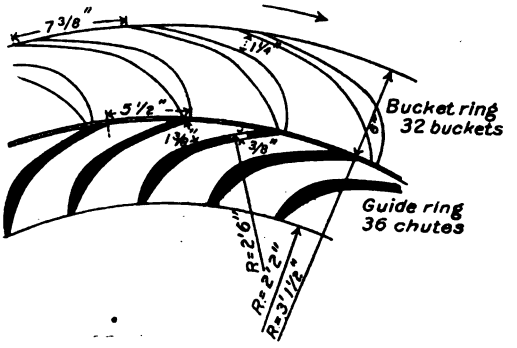


FIG. 4.—Section of guides and buckets, Fourneyron turbine, Niagara Falls.

A Fourneyron turbine similar to that at Niagara Falls has been erected at Trenton Falls, N. Y. This turbine operates under 265 feet gross head and has 37 buckets, each 5½ inches deep and $\frac{13}{16}$ inch wide at the least section. The total area of outflow at the minimum section is, therefore, 165 square inches. How enough water can pass through so small an aggregate aperture to yield continuously 950 horsepower is a matter for legitimate wonder.

### PARALLEL DOWNWARD-FLOW TURBINE—THE JONVAL TURBINE.

The idea of a parallel-flow turbine is said to have originated with Euler. M. Fontaine put it into form for practical use, and M. Jonval added the draft tube from which it bears his name.

In 1837 O. Henschel, of Cassel, invented the downward parallel-flow turbine, later known by the name of Jonval or Koechlin. The Jonval turbine closely resembles a later type of flutter wheel known as the Borda turbine, which has inclined floats and receives water from a spout directed downward. The outer ends of the vanes are inclosed in a circular curb. Thus a runner of the Jonval type was derived by easy transitions from the primitive flutter wheel. This wheel receives water at only one point on its circumference. In the Jonval wheel the spout is replaced by a ring of guide chutes, which admit water all around instead of at one point. The Jonval wheel became at once the competitor of the Fourneyron turbine. The Jonval turbine was introduced into America by Elwood Morris and Emile Geyelin, of Philadelphia, about the middle of the nineteenth century.

The tub wheel was a parallel-flow turbine without guides. This was placed in the bottom of a flume and commonly contained a number of inclined or curved vanes, the runner being similar to that of the Borda turbine in its earlier and to the Jonval turbine in its later form. Sometimes but one or two vanes were used, forming a helix or screw wheel. The tub wheel, when fitted with a cover containing guide passages to direct the currents of water against vanes, becomes essentially a Jonval turbine. The tub wheel was in common use in America at the time the Jonval turbine was introduced.

The theory of the design of the Jonval turbine forms a neat problem in applied mathematics, and is extensively discussed by various writers.[a]

[a] See bibliography, pp. 126–130.

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A variation of the Jonval turbine, in which the number of buckets was reduced to two, was extensively used in sawmills in northern New York. Owing to the large openings of the buckets, ice, drift, and other obstructions could pass through this wheel without injuring it. The vanes were nearly horizontal, giving a high speed of rotation. The efficiency was very low.

In the Jonval turbine the velocity of water at the outer ends of the buckets is greater than that at the inner ends. In order to increase the capacity of the wheel without the loss of power that would result from unequal velocities in the outer and inner portions of a broad

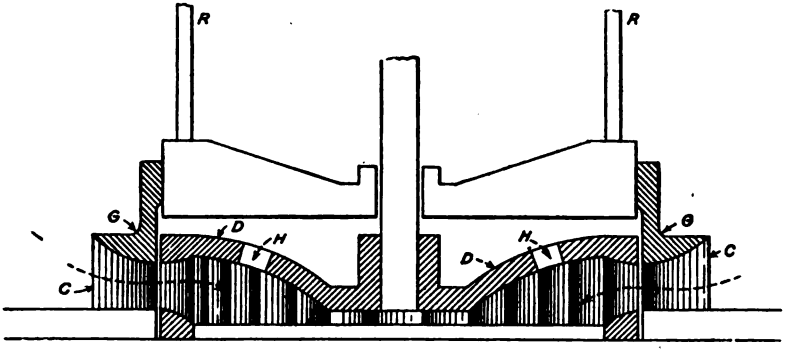


FIG. 5.—Section of Francis center-vent turbine at Booth Cotton Mills, 1849. *C*, Guide chutes; *D*, runner; *G*, inside cylinder gate ring; *H*, holes through runner disk to admit water and neutralize pressure; *R*, gate stems.

bucket annulus, the Geyelin Double Jonval turbine has been devised. This contains two rings of buckets, one within the other, the inclinations of the buckets differing, so that the angular velocity of both rings is the same; the intention being to secure a turbine of large capacity in small compass.

Jonval turbines are still manufactured by a number of American firms, and rating tables are given on pages 98–100.

### RADIAL INWARD-FLOW TURBINES—THE FRANCIS TURBINE.

James B. Francis, who was intimately associated with Uriah A. Boyden in testing early American Fourneyron turbines, experimented in 1847 on a model of a center-vent turbine which was essentially a Fourneyron turbine having the relative positions of the guides and buckets and the direction of flow reversed.[a] Such a wheel had been proposed by Poncelet in 1826. A patent was issued to Samuel B. Howd, of Geneva, N. Y., in 1836 for an inward-flow turbine, some features of which were embodied in the Francis turbine.

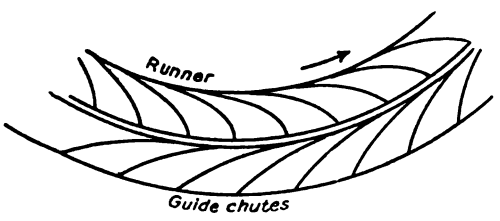


FIG. 6.—Section of runner of Francis center-vent turbine.

The inward-flow turbine was destined to supplant all others, but it was soon found best to extend the buckets downward, thus making an inward and downward flow turbine.

### MIXED-FLOW TURBINES.

This class includes (A) scroll central-discharge wheels, embracing (1) turbines without guides, (2) the Burdin turbines, (3) Thompson vortex turbine; (B) early American types of turbines having double curved buckets extended downward below the guide ring, but not protruding outward. In these wheels the runner can be lifted vertically out of the case.

[a] Francis, J. B., Lowell Hydraulic Experiments, pp. 55–60.

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### SCROLL CENTRAL-DISCHARGE WHEELS.

Scroll-case turbines have flat vanes, or vanes that are curved but little from a vertical plane. The action of the water is chiefly radially inward, although the discharge is both upward and downward.

The best developed turbine of the scroll central-discharge type is the Schiele, which has curved guide vanes and buckets, the latter attached to periphery of a central drum. (See fig. 7.) The discharge is controlled by a gate in the chute.

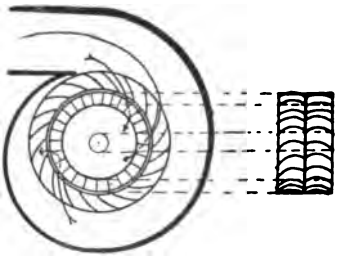

FIG. 7.—Schiele turbine.

The Thompson vortex turbine and certain American types of bulging-bucket turbines mounted in scroll cases also discharge both upward and downward. Many scroll central-discharge turbines, with no guide passages and with the controlling gate in the throat of the scroll case, are still in use. The gate is either of the sliding or of the pivoted butterfly type. Some forms of this wheel have rudimentary guide passages, two in number, opening on opposite sides of the runner, their object being to distribute the water equally around the periphery of the wheel, and to prevent a portion of the runner from "running dry."

### AMERICAN TYPE OF TURBINES.

The earliest step toward the development of the turbine in America is a patent issued to Benjamin Tyler, of Lebanon, N. H., in 1804, signed by Thomas Jefferson, for an "improvement in water wheels." Apparently the water wheel improved is a primitive flutter wheel or rouet volante, and the improvement consisted in hooping the wheel with iron hoops and setting the wooden vanes at a specified angle.

Credit for the scroll case is assigned by W. W. Tyler to the Parker brothers, of Licking County, Ohio, the American patentees of the draft tube in the early half of last century.[a]

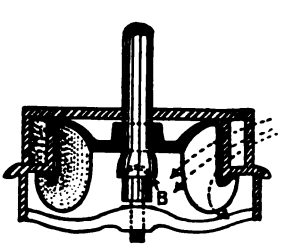


FIG. 8.—Cross section of an early turbine with deep, bulging buckets, pivot gates, and an adjustable bearing (*B*).

From 1850 to 1875 many turbines were built nearly on the lines of the Howd-Francis turbine, but with buckets curved downward to an increasing extent in successive forms. Tests of the Swain wheel in the sixties proved conclusively the merit of this type. In the same decade the pivot or wicket gate was successfully applied in the "American" and "Leffel" turbines, and thus a step in advance was taken toward improvement of the part-gate efficiency of turbines. Leffel also introduced the short draft tube, carrying the bridge tree and step bearing, giving the turbine case practically the form at present retained. The Risdon turbine having an inside cylinder gate and buckets slightly curved downward led in efficiency at the tests made at the Centennial Exposition of 1876. At this exposition much attention was also attracted by tests of the Little Giant turbine, manufactured by Knowlton & Dolan, of Indianapolis, under a patent issued to Matthew and John Obenchain. This wheel has ladle-shaped bulging buckets, and similar wheels were soon devised by John B. McCormick, from whose designs the Hercules, Hunt, Victor, and several makes of "McCormick" turbines have been developed.

In figure 8 the arrows indicate the inward and downward direction of flow of the water. Provision is made for a slight outward flow. In turbines of this type, as well as in those

[a] Tyler, W. W., Evolution of the American Type of Water Wheel.

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*A*. RECENT AMERICAN TYPE OF WATER-WHEEL RUNNER.

*B*. DYNAMOMETER, HOLYOKE TESTING FLUME.

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with inward and downward flow only, the buckets are commonly made of wrought iron or steel secured in a cast-iron head, as here shown, and strengthened by a band at *C*.

Clemens Herschel writes:[a]

American turbines are mostly of a complex nature, as regards the action of the water on the buckets of the wheels, and have been perfected in efficiency by test, or, as it is irreverently called, by the "cut and try" method of procedure. A wheel would be built on the inspiration of the inventor, then tested in a testing flume, changed in a certain part, and retested, until no further change in that particular could effect an improvement. Another part would then undergo the same process of reaching perfection, and thus in course of time the whole wheel would be brought up to the desired high standard of efficiency.

The American type of turbine is distinguished by the great depth of its buckets, its great capacity in proportion to its diameter, and by its high speed. It is also distinguished by the form of its buckets, which consist of a ring of curved vanes arranged parallel to the axis and inclosed within the guide ring. Below the guide ring the buckets expand downward and outward, forming large cup-shaped outlets.

The evolution of turbines having enormous capacity compared with their size is largely the result of the desire for great power in a small and consequently cheap wheel, and the desire to procure as high a speed as possible. The speed of a wheel under a given head varies inversely as its diameter. To increase the capacity of a turbine without increasing its diameter requires an increase in its depth. Thus wheels with very deep buckets have been evolved. This is illustrated in Pl. I, *A*, showing the inlet end of the runner of a deep-bucket wheel.

When a wheel is operating under low heads the lower part of a deep bucket is operating under an appreciably greater head than the upper part; hence to maintain a proper velocity of the water passing through the turbine, and to enable it to leave the runner with a low velocity, large bucket outlets are required. These could not be obtained in the narrow compass of a runner of small diameter, and to remedy this defect large cup-shaped buckets protruding downward and outward from the inlet chutes were devised. The course of the water in passing through these complex buckets is first radially inward, then axially downward, then tangential, or outward or both, thus effecting a nearly or quite perfect reversion of current direction. The large ladle-shaped vents perform another important function in that they distribute the water uniformly within the draft tube.

Recent improvements in this form of wheel have been (1) the arranging of wheels in pairs on horizontal shafts, made possible by the use of the draft tube; (2) the invention of a governor that will control the speed of the wheel with a degree of uniformity that is comparable with that effected by the best engine regulators; (3) the development of such a relation between the gate mechanism and the runner design as to give a high efficiency with a considerable range of gate opening.

American turbine practice differs from European practice in that water wheels are placed on the market in standard or stock sizes, whereas in Europe, notably on the Continent, each turbine is designed for the special conditions under which it is to operate, the designs being based on mathematical theory and following chiefly the Jonval and Fourneyron types.

Thirty years ago there were probably more establishments engaged in the manufacture of turbines than there are to-day. The keen competition of that time led to the development of better turbines, and the relatively small number of firms having the ingenuity and the facilities to meet the demand are the ones that have survived. At the present time a large majority of the turbines used in this country are built in half a dozen factories.

Having been developed by experiment after successive Holyoke tests (described on pp. 36–37), American stock pattern turbines probably give their best efficiencies at about the head under which those tests are made—i. e., 14 to 17 feet. The shafts, runners, and cases are so constructed as to enable stock sizes of wheels to be used under heads ranging from 6 to 60 feet. For very low heads they are perhaps unnecessarily cumbersome. For heads exceeding 60 feet American builders commonly resort to the use of bronze buckets and "special wheels," not designed along theoretical lines, as in Europe, but representing modifications of the standard patterns.

[a] Cassier's Magazine, Niagara power number, July, 1895, p. 243.

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### TYPES OF TURBINE GATES AND GUIDES.

Practice as to chutes or guides differs widely. They are usually fewer in number than the buckets. The cogent dogma of water-wheel design is that the water should enter without shock and leave without velocity. This implies that the direction of motion of water on leaving the buckets shall be opposite to that of the buckets themselves, and that its velocity relative to the buckets shall be equal to that of the buckets. The water will then have no velocity relative to the earth. This law requires that the water shall enter the buckets at an angle at which it will glide smoothly in without shock. The guide passages are made as few in number as is reasonably consistent with this dictum. The construction of turbines without guides has also its advocates.[a]

With regard both to the efficiency and the general merit of the wheel, the gates are perhaps the most important feature. Among the different types of gates are outside register gates, inside register gates, inside cylinder gates, wicket or pivot gates.

Register gates may be of the plate or of the ring type, according as they are applied to parallel-flow or inward-flow turbines. In each class of turbines register gates are sometimes used outside and sometimes inside of the guide chutes.

Outside register gates, adapted to the Jonval type of wheels and to plain inward-flow turbines, were named from their similarity to a common hot-air register. Such wheels are of small capacity in proportion to their weight and diameter. Obstructions readily catch in the gate and chute openings and prevent the gates from being closed tightly, and the downward pressure of the water on the register ring makes it difficult to open. When the register is partially closed, the usefulness of the guide passages is in part nullified and the resulting efficiency of the wheel is diminished.

The inside register gate is placed between the chute ring and wheel runner instead of being outside of both. It is sometimes applied to wheels of the American type having inlet passages parallel to the axis as well as to Jonval wheels, in which the inlet passages are in a plane at right angles to the wheel axis.

Cylinder gates are applied to turbines of the Fourneyron and American types, but not to Jonval turbines. The cylinder gate moves over the inlet ports in a direction parallel to its axis, cutting off the supply at the top of the guide passages instead of at the side, as does a register gate.

The inside cylinder gate is the form of gate most commonly used on wheels of the American type. It consists of a cast ring having a width equal to the depth of the inlet of the buckets, supported by counterbalance weights and moved by gearing. By moving it up or down the depth of the inlet passages is increased or diminished as desired. It is commended by its ease of operation and its freedom from clogging. When it is partially closed the contraction of the water in passing the sharp metal lip of the gate causes swirls and eddies to form in the upper part of the buckets. The smooth curved form of the guide passages is fully effective only when the wheel is running with the gate wide open. In order to lead the water smoothly into the buckets at all gate openings, a set of "false guides," or garnitures, is sometimes attached to the lip of the gate cylinder to prevent the breaking or throttling of the inflowing water.[b]

Another device intended to prevent inefficient operation when the buckets are only partially filled, as at part gate, consists in the use of division plates, by which the water is entirely shut out of the upper part of the wheel when it is operating at part gate. This makes the turbine, in effect, a series of water wheels placed one above another. Such water wheels are commonly called double turbines. They may, however, be distinguished from another style of double turbines, the Leffel, in which two essentially different wheels are combined and mounted on the same shaft for the purpose of increasing the capacity of the turbine without increasing its diameter.

When an inside cylinder gate is raised, an open space an inch or more wide is left between the guide chutes and buckets. In order to avoid this and to conduct the water

[a] Tyler, W. W., The evolution of the American type of water wheel: Jour. Western Soc. Eng., vol. 3. Chicago, 1898.

[b] Webber, Samuel, Efficiency of turbines as affected by form of gate: Trans. Am. Soc. Mech. Eng., 1892.

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more perfectly to the wheel, an outside cylinder gate has been devised, called a "sleeve gate," consisting of a cylindrical ring slipping outside of both runner and chute ring.

Wicket or pivot gates, as the terms are applied to the American type of turbines, are a combination of gates and guide passages. The leaves of the guide ring are so pivoted on their centers as to balance and swing by levers and gearing. Their inner ends approach or recede from one another, increasing or cutting off the supply to the wheel runner as desired. As usually constructed, all the gate leaves move simultaneously; a modification consists in a series of hinged gates, which close one after another as it is desired to decrease the power. When a gate is opened at all, it is opened full width, and the number of fractional gate openings at which the wheel can operate is determined by the number of gates.

Pivot or wicket gates are conducive to high part-gate efficiency provided they are so constructed as not to change the "entrance angle" of the water as it strikes the buckets at part gate. Cylinder-gate turbines may be so designed as to yield their maximum efficiency when running at about three-fourths gate, the depth of buckets being so great that the discharge is "choked" and some efficiency lost at full gate. In this way a good efficiency scale for part gate is obtained with cylinder-gate turbines.

Pivot gates contain many parts and are as a rule more liable to obstruction, leakage, and breakage than cylinder gates. They are, however, extensively used with very satisfactory results.

## MECHANICAL PRINCIPLES OF THE TURBINE.

No attempt will be made to enter into the mechanical principles of the turbine from a mathematical standpoint, as the theoretical equations of relation are long, involved, and voluminous in development. Only a very general discussion of the subject will therefore be given.

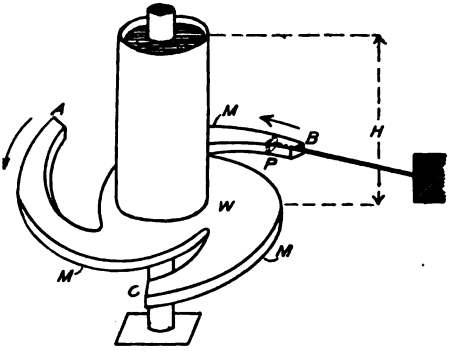


FIG. 9.—Diagram illustrating the principle of reaction. The figure represents a Barker's mill of the Whitelaw type.

The principle of reaction, as operating in turbines, is illustrated in fig. 9. If the wheel $W$ were held rigid, the water would spout from the orifices $A$, $B$, and $C$ with a velocity due to the head $H$. If pistons similar to $P$ were fitted in the orifices, these pistons would be driven outward by the pressure. If, now, the pistons were held rigid, but the wheel were free to revolve, the pistons would be forced outward as before relative to the wheel, but the wheel must then revolve. The water head $H$ exerts a direct pressure on the pistons, and in accordance with Newton's second law of motion, an equal and opposite pressure or reaction is exerted outward against the back walls $M$, $M$, $M$ of the arms $A$, $B$, and $C$. Similarly, if the pistons were removed, and if the wheel were free to revolve, the unbalanced pressure against the back or outer walls $M$, $M$, $M$ of the arms would cause it to revolve and with a peripheral velocity nearly equal to that due to the head $H$.

The theorem of Torricelli requires that the water shall issue from an orifice with a velocity equal to that acquired by a body falling through a height equal to the head.

In the case of the Barker's mill the orifice itself is moving with this velocity and in a contrary direction. Hence the water will have the required velocity relative to the wheel, but will have no velocity relative to the earth and will drop nearly inert from the orifices. This simple phenomenon has been carefully traced out, in order that its application in the less evident example of a turbine bucket may be made clear.



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Let *A*, fig. 10, represent a single bucket in the vane ring of an outward-discharge turbine, the inner or guide ring being removed. Assuming the bucket to be attached to the axis of the turbine by the radial arm *B*, the similarity of conditions to those shown in fig. 9 is obvious.

This illustration applies equally well to either an outward, inward, or downward discharge turbine, so far as reaction is concerned.

Inasmuch as the bucket *A* revolves, the water must enter the bucket, if at all, with a tangential velocity equal to the velocity of the bucket and in the same direction. Guide chutes facilitate the action by properly directing the current of water in entering the bucket, as indicated at *C*, fig. 10.

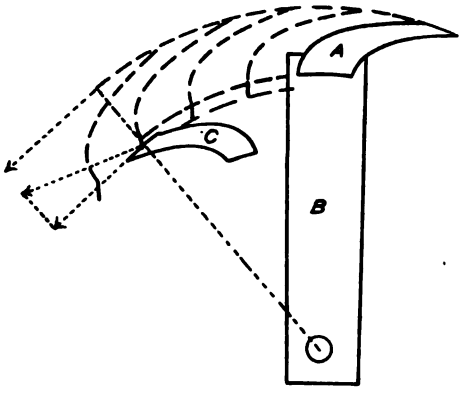


FIG. 10.—Diagram illustrating impulse against curved vanes.

Action by impulse against a moving vane takes place as follows:

First consider the vane *V*, fig. 11, as stationary. The jet from a guide chute enters the bucket in the direction *A B* and leaves it in the direction *C D*, so that its direction of motion is changed through the angle *B E C*.

If the water spouting from the guide chute *A* would have reached *B* at the same time that it actually reaches *C*, then *A C* would represent the resultant velocity. The line *A C* comprises two components—(1) the initial velocity *A B* and (2) a velocity imparted by the vane *V*. From the parallelogram of forces we find graphically for the latter the value *B C*. This force is exerted as a push against the vane, tending to rotate it on its axis. It can do work by causing the vane to move forward or to revolve against resistance, and the amount of work done will be represented by a component of the force *B C* (modified by the motion of the vane) parallel to the line of motion and acting through the distance *v* where *v* is the velocity of the vane—i. e., the velocity of rotation of a turbine.

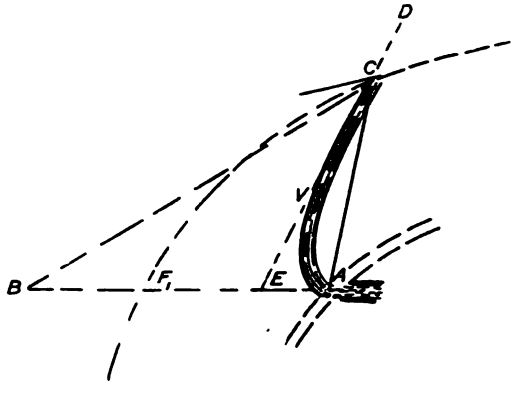


FIG. 11.—Diagram illustrating theory of moving vanes.

If the vane *V* were properly curved and moved with such velocity relative to that of the jet that the jet left its outer end with a backward velocity equal to the forward velocity of the wheel, then the jet would have no velocity relative to the earth and would drop inert, its entire energy having been imparted to the vane.

With most forms of gates the size of the jet is decreased as the gate is closed, the bucket area remaining unchanged, so that the wheel operates mostly by reaction at full gate and by impulse to an increasing extent as the gate is closed. Hence, the speed of maximum efficiency varies as the gate is closed. The ratio $\frac{\text{peripheral velocity}}{\text{velocity due head}}$ for maximum efficiency for a 36-inch Hercules turbine is given in the subjoined table.

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*Velocity at various gate openings for a 36-inch Hercules cylinder-gate turbine.*

| Proportional gate opening. | Maximum efficiency. | Peripheral velocity. Velocity due head. |
|---|---|---|
| | *Per cent.* | |
| Full. | 85.60 | 0.677 |
| 0.806 | 87.1 | .648 |
| .647 | 86.3 | .641 |
| .489 | 80 | .603 |
| .379 | 73.1 | .585 |

Centrifugal force also plays an important part in turbine action. The complete theory of the turbine, including consideration of friction and centrifugal force, involves intricate mathematical analysis. The principal results to which it leads are as follows:

Given the head and quantity of water and speed required, theory indicates the diameter of wheel and the initial and terminal angles of the vanes. It does not determine the form of the vanes, the curved surfaces of which are usually made up of circular arcs for simple inward-, outward-, and downward-flow turbines. Neither is the number or the depth of the buckets determined, except that their normal sections shall be such as to give the water the required velocities in passing through.

Theory does not indicate the numbers of guides or buckets most desirable. If, however, they are too few, the stream will not properly follow the flow lines indicated by theory. If the buckets are too small and too numerous, the surface-friction factor will be large.

It is customary to make the number of guide chutes greater than the number of buckets, so that any object passing through the chutes will be likely to pass through the buckets also.

In a Jonval turbine the guide ring and bucket ring have equal radii. In the Francis, Thomson, and American types the radius of the guide ring is larger, requiring oftentimes the thickening of the guide partitions in order to give the water the proper initial velocity where it enters the buckets.

## HORSEPOWER AND EFFICIENCY OF TURBINES.

The energy or capacity for doing work resulting from a weight $W$ falling through a height $H$ is—

$$\text{Energy in foot-pounds} = W\,H.$$

A horsepower was defined by James Watt as the capacity to perform work at the rate of 33,000 foot-pounds of energy expended per minute.

If the weight of a cubic foot of water is $w$ and the flow of a stream is $Q$ cubic feet per minute, then the theoretical horsepower will be—

$$\frac{W\,H}{33{,}000} = \frac{Q\,w\,H}{33{,}000}$$

Taking $w$, the weight of water, at 62.4 pounds per cubic foot, the factors for obtaining the theoretical horsepower are the following:

$0.1135 \times H \times$ cubic feet per second.

$0.00189 \times H \times$ cubic feet per minute.

$0.000253 \times H \times$ U. S. gallons per minute.

$0.3643 \times H \times$ U. S. gallons per 24 hours.

$0.00227 \times H \times$ California miner's inches (=0.02 second-foot).

$0.00295 \times H \times$ Colorado miner's inches (=0.026 second-foot).

$0.000789\sqrt{2g} \times H^{\frac{3}{2}} \times V$ (vent in square inches).

$0.00632 \times H^{\frac{3}{2}} \times V$ (vent in square inches).

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The horsepower of a stream decreases about one-fourth of 1 per cent with a variation of the temperature of the water from 40° to 75° F.

For precise calculations the exact weight of pure water may be useful.

*Weight and dimensions of distilled water at stated temperatures.*[a]

[Weight in pounds.]

| Temperature, degrees Fahrenheit. | Relative density. | Weight per cubic foot. | Weight per cubic inch. | Weight of column 1 inch square, 1 foot high. | Weight per U. S. gallon. | Cubic feet per ton. | Weight per cubic yard. |
|---|---|---|---|---|---|---|---|
| 32 | 0.99987 | 62.416 | 0.0361 | 0.4334 | 8.345 | 32.043 | 1,685.232 |
| [b]39.3 | 1.00000 | 62.424 | .0361 | .4335 | 8.3454 | 32.039 | 1,685.448 |
| 50 | .99975 | 62.408 | .0361 | .4333 | 8.3433 | 32.047 | 1,684.908 |
| 60 | .99907 | 62.366 | .0361 | .4330 | 8.3383 | 32.069 | 1,683.882 |
| 70 | .99802 | 62.300 | .03607 | .4326 | 8.3295 | 32.103 | 1,682.100 |
| 80 | .99669 | 62.217 | .03602 | .4320 | 8.3184 | 32.145 | 1,679.859 |

[a] Smith, Hamilton, Hydraulics. [b] Maximum density.

In practice the theoretical power is always to be multiplied by an efficiency factor E to obtain the net power available on the turbine shaft as determinable by dynamometrical test.

Manufacturers' rating tables are based on efficiencies usually between 75 and 85 per cent. In selecting turbines from a maker's list it is often important to know the rated efficiency. This may be obtained by the following formula:

E=tabled efficiency.

H. P.=tabled horsepower, and

Q=tabled discharge (C. F. M.) for any head H.

$$E=\frac{33{,}000\times H.P.}{62.4\times Q\times H}=528.8\,\frac{H.P.}{Q\times H}$$

The tabled efficiencies for a number of styles and sizes of turbines are shown in the accompanying table.

*Rated efficiency of water wheels.*

From manufacturers' power tables.]

| Name of wheel. | Diameter in inches. | Percentage of efficiency at 10-foot head. | Percentage of efficiency at 40-foot head. |
|---|---|---|---|
| Hercules | 24 | 81.520 | 79.838 |
| Do | 48 | 79.855 | 79.858 |
| Samson | 20 | 80.800 | 80.809 |
| Do | 45 | 80.754 | 80.885 |
| United States (Camden) | 24 | 79.877 | 79.944 |
| Do | 48 | 79.869 | 79.932 |
| Smith-McCormick | 24 | 80.004 | 79.913 |
| Do | 48 | 79.945 | 79.905 |
| New Success | 24 | 80.000 | 79.906 |
| Do | 48 | 79.937 | 79.905 |
| Lesner No. 1 | 22 | 80.110 | 79.841 |
| Do | 44 | 80.010 | 80.126 |
| New American | 26 | 79.830 | 79.880 |
| Do | 48 | 79.905 | 79.776 |
| Victor | 24 | 79.914 | 79.936 |
| Do | 48 | 79.914 | 79.933 |

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The efficiency at which wheels are rated by the builders varies slightly with the size of the wheel, as well as with the head, in many cases. Owing to the different weights of water assumed, etc., the efficiencies of wheels intended to be rated at 80 per cent differ slightly from that amount where computed from the manufacturer's power tables.

Prior to the classical experiments of James B. Francis on the flow of water over weirs in 1852 at the lower locks in Lowell, the diversity of formulas used for calculating flow through turbines makes the results of early tests incomparable one with another, and the accuracy of some later experiments preceding the building of the present Holyoke testing flume is somewhat in doubt.

It can hardly be said that there has been a progressive growth in the efficiency of turbines, as the following outline of the results of successive series of tests will show:

In 1759 James Smeaton reported tests of 27 undershot water wheels showing efficiencies varying from 28 to 32 per cent. Similar tests of 16 overshot wheels showed efficiencies varying from 76 to 94 per cent.[a]

In 1837 M. Morin tested several Fourneyron turbines. One at St. Blaise showed an efficiency of 85 per cent under 354 feet head. For another, under a lower fall, 88 per cent efficiency is claimed.[b]

In 1843 Elwood Morris introduced and tested Fourneyron turbines in the United States. Turbines in Rockland mills and Dupont powder mills, Wilmington, Del., showed 70 and 75 per cent maximum efficiency, respectively.

In 1844 Uriah A. Boyden built at Lowell the first Fourneyron turbine used in New England, which showed on completion an efficiency of 78 per cent.[c] It is claimed that some of Boyden's later turbines showed an efficiency, on test, of 88 to 92 per cent.

In 1859 and 1860 competitive tests of 19 wheels at Fairmount Park waterworks showed efficiencies as follows:

*Results of tests of turbines at Fairmount Park, Philadelphia, Pa., in 1859–60.*

| Efficiency. | Number of turbines. | Efficiency. | Number of turbines. |
|---|---|---|---|
| 50 per cent or less | 1 | 70 to 75 per cent | 4 |
| 50 to 55 per cent | 2 | 75 to 80 per cent | 3 |
| 55 to 60 per cent | 0 | 80 to 85 per cent | 2 |
| 60 to 65 per cent | 4 | Over 85 per cent | 1 |
| 65 to 70 per cent | 2 | | |

In 1876 Centennial tests showed maximum efficiencies as follows for 17 wheels:

*Results of tests of turbines at Centennial Exposition, at Philadelphia, in 1876.*

| Efficiency. | Number of turbines. | Efficiency. | Number of turbines. |
|---|---|---|---|
| 60 to 65 per cent | 1 | 75 to 80 per cent | 5 |
| 65 to 70 per cent | 3 | 80 to 85 per cent | 4 |
| 70 to 75 per cent | 4 | Over 85 per cent | 1 |

The large majority of turbines sold at the present time are made at the shops of five or six builders whose wheels have been frequently tested. The average full-gate efficiency shown in recent Holyoke tests of standard patterns is close to 80 per cent.

Some early wheels showed very high efficiencies, but prior to the building of the Holyoke flume the large majority were of low efficiencies.

[a] Evans, Oliver, Millwright's Guide, Philadelphia, 1853, pp. 131–154.
[b] Journal Franklin Institute, October to December, 1843.
[c] Francis, J. B., Lowell Hydraulic Experiments.

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During the past thirty years the general standard of efficiency of turbines has been steadily raised, although the maximum attained may not exceed that of some early forms. The uniformity of each maker's wheels, as well as their strength and durability, has increased. This increase in uniformity and durability has been accompanied by a marked development in capacity and by the production of good part-gate efficiencies.

From 15 to 25 per cent of the gross power of the water is wasted by the better class of turbines. This waste is due to the following causes:

1. Shaft friction.
2. Skin friction on the guide and bucket surfaces.
3. Leakage through clearance spaces, etc.
4. Terminal velocity of the water on leaving the wheel.
5. Production of swirls, or vortices, in the water within the turbine, some of the energy of the water being thus converted into internal motion, which is ineffectual in producing power. How this occurs is illustrated in figure 12 (after Vigreux).

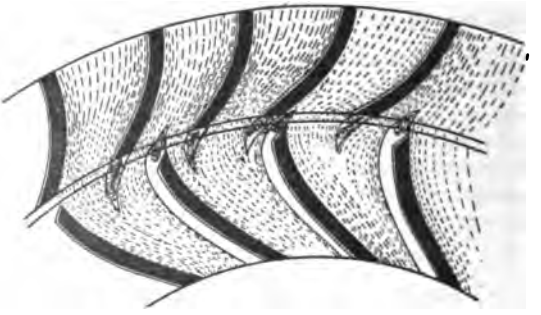

FIG. 12.—Diagram showing interference and formation of eddies in a turbine. (After Vigreux.)

Unwin classifies the lost energy of turbines as follows:[a]

*Classification of lost energy of turbines.*

| Character of loss. | Per cent. |
|---|---|
| Shaft friction and leakage | 10-15 |
| Unutilized energy | 3-7 |
| Friction and shock in guide and wheel passages (i. e., skin friction and internal motion) | 10-15 |
| Total | 26-37 |

There appears to be little probability of further marked increase in turbine efficiency. Compared with steam engines or other forms of prime movers, water wheels yield a larger percentage of the gross power available than any other type of machine or power-yielding medium. The accompanying diagram (fig. 13) shows the efficiency of various prime movers.

## TURBINE TESTING.

### GENERAL REVIEW.

The testing of water wheels may be considered to have begun with the work of James Smeaton, whose results of tests of undershot and overshot water wheels were communicated to the Royal Society of London in May, 1759.

The next important results are those of General Morin, in 1837, from early turbines of the Fourneyron type. General Morin's experiments represent a very high grade of scien-

[a] Unwin, W. C., On the Development and Transmission of Power, p. 104.

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tific research and have formed the pattern for later work. These results have been translated into English by Elwood Morris, and are worthy of examination by students of hydromechanics.[a]

Tests of American Fourneyron turbines were made by Elwood Morris in 1843. From 1844 to 1851 important tests of Fourneyron and Francis turbines were made by Uriah A. Boyden and James B. Francis. These tests included Boyden-Fourneyron turbines con-

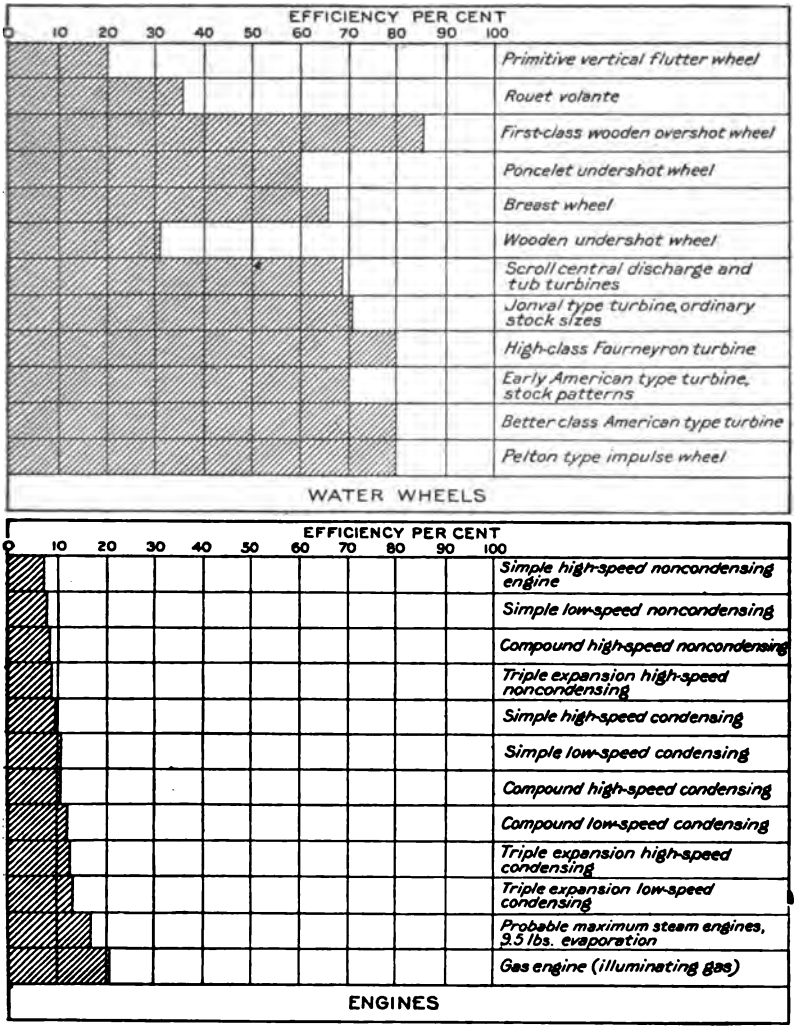


FIG. 13.—Diagram showing efficiency of various prime movers.

structed for the Appleton Mills in 1846, under an agreement in which Mr. Boyden was to receive a bonus of $400 for every 1 per cent of power in excess of 78 per cent efficiency. The computations of these tests were made by James B. Francis, who found a mean maximum efficiency of 88 per cent. Mr. Boyden was accordingly awarded $4,000 premium.

In 1859 and 1860 a series of competitive tests was carried out by the city of Philadel-

[a] Journal Franklin Institute, October to December, 1843.

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phia at Fairmount waterworks, by Henry P. M. Birkinbine, chief engineer. The wheels tested were chiefly of the scroll, spiral, and Jonval types. Efficiencies from 47 to 82 per cent were obtained, with the exception of one wheel of the Jonval type, reported to have yielded 88 per cent.

Before the development of turbine testing at Holyoke is considered, mention may be made of the Centennial tests of 1876, results of which are given on pages 25–29. These tests did much to stimulate improvement in general efficiency and enlargement of capacity of American type turbines.

In 1868 a testing flume was constructed by A. M. Swain at Lowell from designs by James B. Francis. James Emerson was engaged to construct a Prony brake and conduct the tests. Tests of the Swain wheel were also made by Mr. Boyden and Mr. Francis and the Lowell flume was opened to the public, under the charge of Mr. Emerson, who conducted it as a personal enterprise, paying for the water used.

In 1871 and 1872 a new testing flume was erected at Holyoke, and continued under the charge of James Emerson until about 1880. An important series of tests was made in this flume by the Holyoke Water Power Company in 1879 and 1880 under the personal supervision of Theo. G. Ellis, Samuel Webber, and James Emerson. The wheels tested at this time were chiefly of the early American type, having both inward and downward discharge.

In 1882 the present testing flume of the Holyoke Water Power Company, designed by Clemens Herschel, was completed. The growth of the water-wheel testing at the Holyoke flume is illustrated by the following table, from data furnished by A. F. Sickman, hydraulic engineer of the Holyoke Water Power Company:

*Growth of turbine testing at Holyoke testing flume.*

| Year. | Serial number of first test. | Number of wheels tested during year. | Year. | Serial number of first test. | Number of wheels tested during year. |
|---|---|---|---|---|---|
| 1881 | 36 | 43 | 1893 | 650 | 84 |
| 1882 | 79 | 52 | 1894 | 734 | 80 |
| 1883 | 131 | 96 | 1895 | 814 | 69 |
| 1884 | 227 | 67 | 1896 | 883 | 87 |
| 1885 | 291 | 19 | 1897 | 970 | 99 |
| 1886 | 310 | 38 | 1898 | 1069 | 96 |
| 1887 | 348 | 48 | 1899 | 1165 | 57 |
| 1888 | 396 | 45 | 1900 | 1222 | 94 |
| 1889 | 441 | 25 | 1901 | 1316 | 72 |
| 1890 | 466 | 41 | 1902 | 1388 | 54 |
| 1891 | 507 | 54 | 1903 | 1442 | 59 |
| 1892 | 561 | 89 | | | |

## CENTENNIAL TURBINE TESTS.

A series of 22 tests, a résumé of which is given in following tables, were obtained at the United States International Exhibition, Philadelphia, 1876, under direction of Samuel Webber.[a] The effective head utilized in these experiments was about 30 feet, and therefore greater than that used at Holyoke or elsewhere. Many of the turbines were of types that have since come into general use. The results of the tests, therefore, give valuable information relative to the capacity under partial and full gate of a variety of old-type turbines under as great heads as were commonly used thirty years ago.

The water supply for the tests was pumped into an overhead tank of 19,000 gallons capacity by means of two Cataract centrifugal pumps. From this tank it was conducted

[a] See Reports and Awards, U. S. Centennial, vol. 6, pp. 327-367; also Scientific American Supplement, February 17 and March 13, 1877.

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to the flume in which the turbine was contained by a vertical wrought-iron pipe 4 feet in diameter, having a quarter turn at its lower end where it entered the flume. The flume was of wrought iron, 8 feet in diameter and 6 feet in height. The discharge was measured by means of a thin-edged weir placed across the lower end of the brick tailrace. The depth of overflow was determined by means of a hook gage and stilling box 6 feet upstream from the weir, and the discharge was computed by means of the Francis formula. The power was measured by means of a friction dynamometer. Each experiment comprised a record of the water used and of the speed and power at a given load and setting of the gate, covering a period of one or two minutes. Allowance was made for leakage of the flume in the reduction of the experiments.

The water supply was limited to about 1,860 cubic feet per minute, which was found insufficient for proper testing of the Cope and Hunt turbines. Most of the wheels were tested as they came from the shop, without special finish or preparation.

The results of the tests are probably consistent among themselves, although the general accuracy of the tests has been questioned.

*Summary of tests of turbines at the Centennial Exhibition, Philadelphia, 1876.*

20-INCH BARBER & HARRIS.[a]

[Tested September 18, 1876.]

| Gate opening (proportional part). | Number of tests. | Mean head in feet. | Revolutions per minute. | | | | Mean discharge in second-feet. | Mean horse-power. | Percentage of efficiency. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Mean. | At maximum efficiency. | | | Maximum. | Mean. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1.000 | 4 | 31.21 | 354 | 330.5 | 343.6 | 330.5 | 13.622 | 35.677 | 76.08 | 73.43 |
| .875 | 1 | 31.27 | 380.5 | 380.5 | 380.5 | 380.5 | 12.855 | 33.484 | 73.62 | 73.62 |
| .75 | 2 | 31.425 | 299 | 267.5 | 283.25 | 299 | 9.924 | 23.73 | 71.30 | 68.69 |
| .50 | 2 | 31.64 | 271.5 | 227.5 | 249.5 | 271.5 | 6.767 | 14.603 | 71.77 | 60.23 |

30-INCH RISDON.[b]

[Tested September 21, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 3 | 30.37 | 266 | 252.5 | 259 | 266 | 27.763 | 82.84 | 87.68 | 86.56 |
| .875 | 2 | 30.59 | 257 | 247 | 252 | 257 | 23.446 | 69.53 | 86.20 | 85.60 |
| .75 | 2 | 30.835 | 248 | 238 | 243 | 248 | 20.148 | 57.33 | 82.41 | 81.83 |
| .50 | 3 | 31.03 | 269 | 258 | 263.16 | 258 | 15.949 | 41.78 | 75.35 | 74.55 |

24-INCH KNOWLTON & DOLAN.[c]

[Tested September 23, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 6 | 30.763 | 333.5 | 282.5 | 307.75 | 333.5 | 25.281 | 67.47 | 77.43 | 76.68 |
| .875 | 3 | 30.863 | 299.5 | 283.5 | 291.83 | 299.5 | 22.581 | 58.323 | 73.34 | 72.69 |
| .50 .625 | 4 | 31.19 | 270.5 | 233 | 250.88 | 233 | 15.929 | 34.99 | 62.73 | 62.24 |

[a] Made by Barber & Harris, Meadford, Ontario.
[b] Made by T. H. Risdon & Co., Mount Holly, N. J.
[c] Made by Knowlton & Dolan, Logansport, Ind.

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*Summary of tests of turbines at the Centennial Exhibition, Philadelphia, 1876*—Continued.

24-INCH WOLFF.[a]

[Tested September 25, 1876.]

| Gate opening (proportional part). | Number of tests. | Mean head in feet. | Revolutions per minute. | | | | Mean discharge in second-feet. | Mean horse-power. | Percentage of efficiency. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Mean. | At maximum efficiency. | | | Maximum. | Mean. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1.000 | 7 | 30.58 | 305 | 266 | 290.07 | 297 | 27.349 | 68.12 | 72.75 | 72.03 |
| .75 | 2 | 30.81 | 297.5 | 276.5 | 287 | 276.5 | 21.911 | 53.83 | 71.50 | 70.30 |
| .50 | 1 | 31.08 | 287.5 | 287.5 | 287.5 | 287.5 | 15.256 | 34.50 | 64.90 | 64.90 |
| .333 | 2 | 31.425 | 282.5 | 272.5 | 277.5 | 272.5 | 12.024 | 25.51 | 60.22 | 59.75 |

24-INCH WOLFF[a] (SECOND TEST).

[Tested October 15, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 7 | 30.15 | 320 | 267.5 | 296.21 | 320 | 25.451 | 64.423 | 74.80 | 73.62 |
| .75 | 2 | 30.5 | 309 | 298 | 299 | 298 | 19.430 | 49.03 | 74.00 | 72.75 |
| .625 | 1 | 30.83 | 284 | 284 | 284 | 284 | 15.028 | 34.08 | 65.00 | 65.00 |
| .50 | 2 | 30.89 | 290 | 271 | 280.5 | 290 | 12.996 | 28.01 | 61.60 | 61.54 |

24-INCH NOYES & SONS.[b]

[Tested September 26–27, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 8 | 30.976 | 325 | 269 | 301.812 | 317 | 16.035 | 35.29 | 65.66 | 62.80 |
| .875 | 1 | 31.16 | 317 | 317 | 317 | 317 | 14.326 | 32.97 | 65.46 | 65.46 |
| .75 | 3 | 31.206 | 314 | 289 | 301 | 289 | 13.657 | 28.83 | 61.27 | 59.94 |
| .625 | 1 | 31.29 | 293 | 293 | 293 | 293 | 11.237 | 25.78 | 64.80 | 64.80 |
| .50 | 3 | 31.28 | 289.5 | 256.5 | 272.83 | 256.5 | 10.787 | 19.55 | 52.52 | 51.34 |

30-INCH E. T. COPE & SONS.[c]

[Tested October 19, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 13 | 29.88 | 274 | 223 | 250.08 | 258 | 27.605 | 65.75 | 78.7 | 70.07 |

25-INCH TAIT.[d]

[Tested October 23, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 10 | 31.038 | 331 | 243 | 288.7 | 288.5 | 15.939 | 44.198 | 82.03 | 79.28 |
| .75 | 3 | 31.32 | 322.5 | 292 | 305.67 | 292 | 11.6297 | 29.26 | 72.6 | 70.8 |
| .50 | 3 | 31.44 | 277.5 | 258 | 266.83 | 258 | 9.59 | 22.387 | 66.2 | 65.43 |
| .25 | 3 | 31.537 | 268.5 | 245 | 259.51 | 265 | 6.541 | 12.423 | 54.5 | 53.1 |
| .20 | 2 | 31.595 | 255 | 235 | 245 | 255 | 4.824 | 7.33 | 46.9 | 44.95 |
| .125 | 2 | 31.61 | 277 | 266 | 271.5 | 266 | 4.702 | 5.96 | 37.7 | 35.3 |

[a] Made by A. N. Wolff, Allentown, Pa.
[b] Made by John T. Noyes & Sons, Buffalo, N. Y.
[c] Made by E. T. Cope & Sons, West Chester, Pa.
[d] Made by Thomas Tait, Rochester, N. Y.

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*Summary of tests of turbines at the Centennial Exhibition, Philadelphia, 1876*—Continued.

36-INCH GEYELIN DUPLEX.[a]

[Tested October 31, 1876.]

| Gate opening (proportional part). | Number of tests. | Mean head in feet. | Revolutions per minute. | | | | Mean discharge in second-feet. | Mean horse-power. | Percentage of efficiency. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Mean. | At maximum efficiency. | | | Maximum. | Mean. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| .50 | 13 | 30.235 | 260 | 181 | 221.3 | 190 | 17.189 | 39.980 | 71.4 | 67.78 |

36-INCH GEYELIN DUPLEX.[a]

[Tested November 2, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 9 | 29.547 | 223.5 | 185.5 | 200.9 | 217.5 | 26.52 | 68.24 | 78.1 | 76.77 |

36-INCH GEYELIN SINGLE.[a]

[Tested November 3, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 7 | 29.58 | 213.5 | 190.5 | 204.93 | 213.5 | 24.837 | 66.196 | 83.3 | 79.41 |

24-INCH RODNEY HUNT.[b]

[Tested November 9, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 6 | 29.282 | 328 | 276 | 302.67 | 295 | 30.754 | 79.60 | 78.7 | 77.95 |
| .50 | 3 | 30.25 | 312 | 287.5 | 299.83 | 312 | 21.395 | 50.31 | 68.72 | 68.57 |
| .75 | 4 | 29.655 | 306 | 278 | 292.75 | 298<br>289 | 27.849 | 66.65 | 71.40 | 71.22 |
| .333 | 4 | 30.455 | 266 | 223 | 245.25 | 266 | 18.507 | 32.227 | 51.30 | 50.35 |

30-INCH STOUT, MILLS & TEMPLE.[c]

[Tested November 10, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 7 | 29.464 | 245.5 | 201 | 226.143 | 231 | 27.95 | 63.091 | 68.4 | 67.53 |
| .50 | 4 | 29.59 | 259 | 230 | 245.75 | 230 | 22.784 | 50.922 | 69.13 | 66.56 |
| .25 | 3 | 30.95 | 204 | 181 | 189 | 182 | 11.619 | 24.072 | 59.91 | 59.03 |

27-INCH GOLDIE & McCULLOUGH.[d]

[Tested October 2, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 9 | 30.198 | 320 | 281.5 | 299.44 | 281.5 | 27.419 | 73.452 | 82.2 | 78.28 |
| .75 | 2 | 30.14 | 285 | 280 | 282.5 | 280 | 22.848 | 55.36 | 71.93 | 70.96 |
| .625 | 2 | 30.59 | 352 | 350 | 351 | 350 | 22.425 | 39.305 | 54.10 | 50.65 |
| .50 | 2 | 30.65 | 325 | 312 | 318.5 | 312 | 19.980 | 40.715 | 60.5 | 58.6 |

[a] Made by R. D. Wood & Co., Philadelphia, Pa.
[b] Made by Rodney Hunt, Orange, Mass.
[c] Made by Stout, Mills & Temple, Dayton, Ohio.
[d] Made by Goldie & McCullough, Gault, Ontario.

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*Summary of tests of turbines at the Centennial Exhibition, Philadelphia, 1876*—Continued.

30-INCH TYLER.[a]

[Tested October 4, 1876.]

| Gate opening (proportional part). | Number of tests. | Mean head in feet. | Revolutions per minute. | | | | Mean discharge in second-feet. | Mean horse-power. | Percentage of efficiency. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Mean. | At maximum efficiency. | | | Maximum. | Mean. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1.00 | 8 | 30.05 | 294 | 251 | 276.69 | 257 | 27.143 | 71.648 | 79.55 | 77.31 |
| .875 | 1 | 30.10 | 286.5 | 286.5 | 286.5 | 286.5 | 24.017 | 66.47 | 81.09 | 81.09 |
| .75 | 3 | 30.413 | 261 | 246 | 254.5 | 261 | 20.943 | 52.96 | 79.85 | 73.66 |
| .50 | 2 | 30.62 | 260 | 247 | 253.5 | 247 | 18.432 | 42.535 | 77.10 | 66.55 |
| .333 | 1 | 30.80 | 240 | 240 | 240 | 240 | 14.2595 | 34.56 | 69.50 | 69.50 |

30-INCH TYLER[a] (SECOND TEST).

[Tested October 24, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 6 | 30.345 | 294 | 262 | 276.5 | 281 | 27.491 | 69.520 | 74.10 | 73.55 |
| .875 | 1 | 30.50 | 280 | 280 | 280 | 280 | 24.92 | 62.72 | 72.15 | 72.15 |
| .75 | 2 | 30.42 | 268 | 255 | 261.5 | 268 | 21.2672 | 50.31 | 73.00 | 69.00 |
| .625 | 2 | 30.59 | 262 | 218 | 240 | 262 | 18.1905 | 39.45 | 64.20 | 62.30 |
| .50 | 2 | 30.715 | 247 | 242 | 244.5 | 242 | 16.4572 | 34.22 | 60.30 | 59.65 |

26½-INCH BOLLINGER.[b]

[Tested October 10, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 4 | 30.302 | 310 | 292.5 | 300.62 | 292.5 | 23,004 | 54.68 | 70.4 | 69.25 |
| .875 | 2 | 30.46 | 300 | 290 | 295 | 290 | 21.49 | 50.72 | 68.6 | 68.3 |
| .75 | 3 | 30.617 | 306 | 290 | 298.67 | 300 | 18.40 | 40.577 | 63.8 | 62.9 |
| .50 | 2 | 30.805 | 290 | 274.5 | 282.25 | 274.5 | 15.647 | 32.71 | 60.2 | 59.95 |
| .375 | 2 | 30.55 | 291 | 263 | 277 | 263 | 12.895 | 24.265 | 57.2 | 54.3 |

27-INCH YORK, NO. 2.[b]

[Tested October 12, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 12 | 30.504 | 312 | 232 | 274.375 | 246.5 | 20.2244 | 48.755 | 73.6 | 69.65 |
| .875 | 2 | 30.60 | 318 | 300 | 309 | 300 | 18.4685 | 41.95 | 67 | 65.5 |
| .75 | 2 | 30.71 | 290 | 280 | 285 | 280 | 17.229 | 39.88 | 67.45 | 67.0 |
| .50 | 2 | 30.85 | 277 | 268 | 272.5 | 268 | 15.6415 | 35.95 | 67.5 | 66.7 |
| .375 | 2 | 31.015 | 300 | 285 | 292.5 | 285 | 13.555 | 29.22 | 62.01 | 61.33 |

27-INCH YORK, NO. 3.[c]

[Tested October 13, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 9 | 29.972 | 265.5 | 212 | 247.28 | 235 | 22.685 | 45.677 | 66.9 | 59.41 |
| .75 | 4 | 30.42 | 264 | 233 | 247.5 | 233 | 16.822 | 32.592 | 60.58 | 56.58 |

[a] Made by Putnam Machine Company, Fitchburg, Mass.
[b] Made by York Manufacturing Company, York, Pa.
[c] Made by National Water Wheel Company, Bristol, Conn.

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*Summary of tests of turbines at the Centennial Exhibition, Philadelphia, 1876*—Continued.

25-INCH NATIONAL.[a]

[Tested October 18, 1876.]

| Gate opening (proportional part). | Number of tests. | Mean head in feet. | Revolutions per minute. | | | | Mean discharge in second-feet. | Mean horse-power. | Percentage of efficiency. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Mean. | At maximum efficiency. | | | Maximum. | Mean. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1.000 | 11 | 30.186 | 330.5 | 226.5 | 276.13 | 279 | 21.809 | 60.15 | 83.7 | 80.63 |
| .75 | 2 | 30.685 | 312 | 292 | 302 | 292 | 17.076 | 40.995 | 70.5 | 68.9 |

24-INCH CHASE.[b]

[Tested November 6-7 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 11 | 29.725 | 399 | 304 | 356.18 | 355 | 25.794 | 54.802 | 68.30 | 62.99 |
| .75 | 5 | 29.47 | 435 | 325 | 366 | 360.[a] | 23.506 | 51.801 | 67.6 | 65.74 |
| .50 | 3 | 30.073 | 372.5 | 328 | 350.17 | 328 | 18.747 | 36.30 | 57.3 | 56.6 |

24-INCH WILLIAM F. MOSSER.[c]

[Tested October 6, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 1 *a* | 30.56 | ..... | ..... | 300 | ..... | 19.396 | 50.40 | ..... | 75.09 |
| 1.000 | 1 *b* | 30.58 | ..... | ..... | 289.5 | ..... | 19.741 | 50.95 | ..... | 74.60 |
| 1.000 | 1 *c* | 30.58 | ..... | ..... | 276 | ..... | 19.972 | 50.78 | ..... | 73.40 |
| 1.000 | 1 *d* | 30.60 | ..... | ..... | 312.5 | ..... | 19.664 | 50.00 | ..... | 73.43 |
| 1.000 | 1 *e* | 30.60 | ..... | ..... | 326.5 | ..... | 19.189 | 49.63 | ..... | 74.62 |
| 1.000 | 1 *f* | 30.62 | ..... | ..... | 342 | ..... | 18.978 | 49.25 | ..... | 74.80 |
| 1.000 | 1 *g* | 30.65 | ..... | ..... | 356.5 | ..... | 18.676 | 48.48 | ..... | 74.39 |
| 1.000 | 1 *h* | 30.67 | ..... | ..... | 365 | ..... | 18.523 | 46.72 | ..... | 72.68 |
| 1.000 | 1 *i* | 30.90 | ..... | ..... | 310.5 | ..... | 15.808 | 39.74 | ..... | 71.63 |
| 1.000 | 1 *j* | 30.95 | ..... | ..... | 323 | ..... | 15.488 | 38.76 | ..... | 71.48 |
| 1.000 | 1 *k* | 31.00 | ..... | ..... | 335 | ..... | 15.169 | 37.52 | ..... | 70.50 |
| 1.000 | 1 *l* | 31.02 | ..... | ..... | 347 | ..... | 15.028 | 36.09 | ..... | 68.2 |
| 1.000 | 1 *m* | 31.03 | ..... | ..... | 355 | ..... | 14.747 | 34.08 | ..... | 65.74 |
| 1.000 | 1 *n* | 31.10 | ..... | ..... | 312 | ..... | 13.334 | 29.95 | ..... | 63.80 |
| 1.000 | 1 *o* | 31.00 | ..... | ..... | 343 | ..... | 13.029 | 30.18 | ..... | 65.8 |
| Mean..... | | 30.79 | ..... | ..... | 326.23 | ..... | 17.116 | 42.835 | ..... | ..... |

[a] Made by National Water Wheel Company, Bristol, Conn.
[b] Made by Chase Manufacturing Company, Orange, Mass.
[c] Made by William F. Mosser, Allentown, Pa This test has been included in full in order to show the range in variation in discharge resulting from variation of the load and speed, the head and gate opening remaining nearly the same throughout the test.

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## TURBINE TESTS BY JAMES EMERSON, AND THE HOLYOKE HYDRODYNAMIC EXPERIMENTS OF 1879-80.

James Emerson was a man of great mechanical skill and ingenuity, but of limited education. A seaman in early life, he took up water-wheel testing by a mere accident of circumstances, and developed testing flumes at Lowell and Holyoke which were forerunners of the present Holyoke testing flume. The results of his tests, covering the period from 1869 to 1880, may be found in his treatise on hydrodynamics, etc.[a]

As a rule, the proportion of full-gate opening for wheels running at part gate is omitted in his reports. Many of the wheels tested were experimental, but a number of selected tests of types of wheels which have continued in use to the present time are given in the following tables. Cases are very rare where tests of the same turbine are given under widely varying heads. The following data from Emerson's Hydrodynamics are of interest:

*Tests of a 30-inch Rodney Hunt wheel under two heads.*

| Mean head in feet. | Number of tests. | Mean revolutions. | Mean discharge in second-feet. | Ratio of— | | |
|---|---|---|---|---|---|---|
| | | | | Square roots of heads. | Revolutions. | Discharge. |
| 18.35 | 9 | 170.39 | 24.36 | 1.000 | 1.000 | 1.000 |
| 12.16 | 10 | 145.78 | 19.75 | .814 | .855 | .811 |

The discharge is very nearly proportional to the square root of the head, indicating practically constant bucket and guide discharge coefficients throughout this range of heads.

Comparative tests of a 30-inch Tyler wheel, set in a scroll case and in an inside register-gate case, are also of interest. These tests also show the great reduction in efficiency that may result from poor finish, friction, or imperfect balancing of the buckets.

Tests of the Case National wheel show the effect on discharge and power which results from cutting off the supply successively from one-fourth, one-half, and three-fourths of the circumference of the wheel.

The Holyoke competitive tests of 1879–80[b] were carried out in response to a circular issued to turbine builders by the Holyoke Water Power Company, William A. Chase, agent, requesting them to submit turbine water wheels for testing. The tests were made under the general supervision of James Emerson. Check observations were made by Samuel Webber and the computations were submitted to him for verification on the part of the water power company. Theodore G. Ellis represented the interests of the turbine builders. These results are probably more accurate than those hitherto obtained.

A number of tests were made of Victor, American, Hunt, Leffel, Hercules, and other types of turbines from the same patterns as wheels still in use at many places. The most complete of these tests are included in the following tables, together with earlier tests by James Emerson.

Tests of similar wheels have been grouped together for convenience. Results obtained in the Holyoke competition of 1879 and 1880 can be distinguished by date. The tests of a 15-inch Victor wheel, set in a flume, and also with various sized draft tubes, are of interest as being the first recorded tests of this character. They also show the importance of using a draft tube of ample size, perfectly air-tight.

It has been said of Emerson's tests that they frequently showed unaccountable irregularities. Many tests obviously abnormal have been omitted in the present publication. Others are retained chiefly because they give the only available record of the capacity of types of wheels which have been extensively used.

[a] Emerson, James, Treatise Relative to the Testing of Water Wheels and Machinery.
[b] Complete results will be found in "Holyoke Hydrodynamic Experiments," published by Holyoke Water Power Company, Holyoke, Mass., 1880.

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*Summary of James Emerson's tests of turbine water wheels.*

40-INCH LEFFEL, PIVOT GATE.[a]

[Tested October, 1869.]

| Gate opening (proportional part). | Number of tests. | Mean head in feet. | Revolutions per minute. | | | | Mean discharge in second-feet. | Mean horse-power. | Percentage of efficiency. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Mean. | At maximum. efficiency. | | | Maximum. | Mean. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1.000 | 7 | 14.272 | 147.1 | 124 | 136.2 | 132.6 | 37.435 | ..... | 79.7 | 76.0 |
| .93 | 7 | 14.132 | 131.4 | 129.5 | 130.5 | 131.4 | 35.496 | ..... | 79.6 | 79.0 |
| .875 | 1 | 14.21 | 128.9 | 128.9 | 128.9 | 128.9 | 34.536 | ..... | 78.9 | 78.9 |
| .827 | 1 | 14.285 | 126.2 | 126.2 | 126.2 | 126.2 | 32.533 | ..... | 78.3 | 78.3 |
| .818 | 3 | 14.201 | 128.4 | 125 | 127.2 | 125 | 33.277 | ..... | 79.6 | 79.9 |
| .80 | 2 | 14.251 | 127.6 | 126.3 | 127 | 127.6 | 32.904 | ..... | 78.4 | 78.4 |
| .751 | 2 | 14.251 | 123.1 | 115.8 | 119.4 | 123.1 | 30.920 | ..... | 78.7 | 78.7 |
| .747 | 3 | 14.011 | 126.1 | 124.4 | 125.3 | 125.3 | 30.358 | ..... | 79.4 | 79.2 |
| .56 | 5 | 14.642 | 139.9 | 121 | 130.5 | 121 | 23.528 | ..... | 72.0 | 69.56 |
| .373 | 1 | 14.938 | 129.2 | 129.2 | 129.2 | 129.2 | 16.422 | ..... | 67.5 | 67.5 |

30-INCH LEFFEL.[a]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 14 | 15.40 | 201 | 135.5 | 167 | 175 | 24.396 | 28.80 | 74.3 | 68.9 |
| .75 | 1 | 15.65 | 161 | 161 | 161 | 161 | 18.446 | 21.95 | 66.4 | 66.4 |
| .50 | 1 | 16.037 | 165 | 165 | 165 | 165 | 10.624 | 13.13 | 59.1 | 59.1 |

20-INCH CASE NATIONAL, REGISTER GATE.[b]

[Tested August 22, 1872.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 4 | 18.695 | 342.5 | 237.2 | 269 | 237.2 | 11.905 | 18.50 | 76.3 | 73.3 |
| .75 | 4 | 18.84 | 254.5 | 237.5 | 248.2 | 237.5 | 9.291 | 13.23 | 71.2 | 65.9 |
| .50 | 4 | 18.955 | 248.5 | 247 | 247.6 | 247 | 6.506 | 8.01 | 60.4 | 56.4 |
| .25 | 4 | 19.112 | 249 | 197.5 | 232.9 | 249 | 3.266 | 2.74 | 43.8 | 38.4 |

24-INCH CASE NATIONAL, REGISTER GATE.[b]

[Tested September 27, 1872.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 4 | 15.58 | 655.1 | 139.5 | 291.2 | 655.1 | 12.455 | 10.745 | 49.5 | 47.6 |

30-INCH CASE NATIONAL, REGISTER GATE.[b]

[Tested August 19, 1872; 16 chutes, 4 closed at a time.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 1 | 18.35 | 133 | 133 | 133 | 133 | 24.627 | 30.23 | 61 | 61 |
| .75 | 1 | 18.61 | 153 | 153 | 153 | 153 | 15.006 | 18.43 | 58.3 | 58.3 |
| .50 | 1 | 18.78 | 154.5 | 154.5 | 154.5 | 154.5 | 9.817 | 10.53 | 50.5 | 50.5 |
| .25 | 1 | 18.19 | 141 | 141 | 141 | 141 | 5.613 | 4.16 | 37.7 | 37.7 |

[a] Made by James Leffel & Co., Springfield, Ohio.
[b] Made by National Water Wheel Company, Bristol, Conn.

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*Summary of James Emerson's tests of turbine water wheels*—Continued.

40-INCH CASE NATIONAL.[a]

[Tested January 21, 1872; 16 chutes, 4 closed at a time.]

| Gate opening (proportional part). | Number of tests. | Mean head in feet. | Revolutions per minute. | | | | Mean discharge in second-feet. | Mean horse-power. | Percentage of efficiency. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Mean. | At maximum efficiency. | | | Maximum. | Mean. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1.000 | 1 | 17.76 | 163.5 | 163.5 | 163.5 | 163.5 | 32.914 | 48.30 | 72.9 | 72.9 |
| .75 | 1 | 18.40 | 158 | 158 | 158 | 158 | 35.179 | 32.31 | 61.6 | 61.6 |
| .50 | 1 | 18.85 | 158 | 158 | 158 | 158 | 17.192 | 17.59 | 47.9 | 47.9 |
| .25 | 1 | 19.26 | 156 | 156 | 156 | 156 | 10.304 | 4.6 | 20.5 | 20.5 |

50-INCH CASE NATIONAL.[a]

[Tested August, 1873.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 6 | 16.36 | 114 | 92 | 103.5 | 97 | 79.73 | 109 | 74.86 | 73.84 |

20-INCH AMERICAN, PIVOT GATE.[b]

[Tested November 12, 1873.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 1 | 18.85 | 253.5 | 253.5 | 253.5 | 253.5 | 10.109 | 14.97 | 69.38 | 69.38 |

25-INCH AMERICAN.[b]

[Tested November 11, 1873.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 1 | 18.23 | 212 | 212 | 212 | 212 | 19.304 | 28.91 | 72.44 | 72.44 |

36-INCH AMERICAN, PIVOT GATE.[b]

[Tested November 13, 20, 1872.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 2 | 18.63 | 146.5 | 144 | 145.2 | 144 | 28.382 | 45.5 | 76.8 | 75.9 |

42-INCH AMERICAN, PIVOT GATE.[b]

[Tested September 29 and October 6, 1873.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 2 | 17.91 | 118 | 112.5 | 115.2 | 112.5 | 42.549 | 60.18 | 70.95 | 69.88 |

48-INCH AMERICAN, PIVOT GATE.[b]

[Tested January 29, 1874.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 13 | 12.82 | 107.8 | 83 | 94.1 | 107.7 | 48.591 | 54.27 | 83.14 | 75.40 |

60-INCH AMERICAN, PIVOT GATE.[b]

[Tested August 5, 1873.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 7 | 15.24 | 88.1 | 70.5 | 78.4 | 80 | 99.621 | 121.41 | 73.94 | 69.87 |

[a] Made by National Water Wheel Company, Bristol, Conn.
[b] Made by Stout, Mills & Temple, Dayton, Ohio.

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*Summary of James Emerson's tests of turbine water wheels*—Continued.

30-INCH NEW AMERICAN, PIVOT GATE.[a]

[Tested July 2, 1880.]

| Gate opening (proportional part). | Number of tests. | Mean head in feet. | Revolutions per minute. | | | | Mean discharge in second-feet. | Mean horse-power. | Percentage of efficiency. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Mean. | At maximum efficiency. | | | Maximum. | Mean. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1.000 | 8 | 17.74 | 209.3 | 163 | 190.7 | 207.5 | 41.29 | 63.26 | 78.03 | 76.42 |

30-INCH NEW AMERICAN, PIVOT GATE.[a]

[Tested July 7, 1880.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 4 | 17.65 | 210.4 | 201.5 | 205.85 | 201.5 | 41.678 | 64.88 | 78.21 | 77.84 |
| .819 | 3 | 17.70 | 209.5 | 200.5 | 204.33 | 200.5 | 39.325 | 62.66 | 79.64 | 79.49 |
| .764 | 3 | 17.74 | 208.5 | 200 | 203.66 | 208.5 | 38.076 | 60.62 | 79.83 | 79.21 |
| .708 | 2 | 17.77 | 207 | 201.2 | 204.1 | 207 | 36.770 | 59.35 | 80.27 | 80.08 |
| .653 | 3 | 17.81 | 206.7 | 198 | 202.9 | 204 | 35.712 | 56.45 | 80.42 | 78.32 |
| .597 | 3 | 17.85 | 208 | 201 | 204.7 | 201 | 33.684 | 55.77 | 79.89 | 78.93 |
| .542 | 2 | 17.91 | 206 | 204 | 205 | 204 | 31.580 | 49.84 | 78.69 | 77.75 |
| .486 | 3 | 17.96 | 207 | 203 | 204.7 | 203 | 29.309 | 45.57 | 77.00 | 76.38 |
| .431 | 2 | 18.04 | 203 | 197 | 200 | 197 | 27.258 | 41.58 | 74.82 | 74.76 |
| .375 | 2 | 18.12 | 206 | 203 | 204.5 | 206 | 24.391 | 36.71 | 73.58 | 73.38 |
| .32 | 3 | 18.16 | 285.5 | 200.5 | 235.3 | 200.5 | 21.316 | 31.11 | 71.92 | 70.89 |

48-INCH NEW AMERICAN, PIVOT GATE.[a]

[Tested October 14, 1879, and January 3, 1880.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 8 | 16.33 | 110.5 | 101.5 | 106.5 | 108.3 | 92.843 | 132.80 | 77.83 | 77.02 |
| 1.000 | 9 | 13.14 | 109 | 99.0 | 101.2 | 105 | 98.419 | 111.11 | 77.23 | 75.82 |

30-INCH ECLIPSE, REGISTER GATE.[b]

[Tested 1878.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 5 | 19.02 | 184.5 | 165 | 171.9 | 184.5 | 16.849 | 24.01 | 76.28 | 63.94 |

15-INCH VICTOR, CYLINDER GATE.[b]

[Tested March 26, 1878.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 1 | 18.34 | 323 | 323 | 323 | 323 | 16.233 | 29.36 | 87.05 | 87.05 |

[a] Made by Stout, Mills & Temple, Dayton, Ohio.
[b] Made by Stillwell & Bierce Manufacturing Company, Dayton, Ohio.



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*Summary of James Emerson's tests of turbine water wheels*—Continued.

15-INCH VICTOR, REGISTER GATE.[a]

| Gate opening (proportional part). | Number of tests. | Mean head in feet. | Revolutions per minute. | | | | Mean discharge in second-feet. | Mean horse-power. | Percentage of efficiency. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Mean. | At maximum efficiency. | | | Maximum. | Mean. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1.000 | [b]6 | 17.98 | 355 | 300.5 | 335.33 | 347.5 | 16.269 | 30.24 | 92.58 | 91.22 |
| [c]1.000 | 7 | 17.78 | 338.5 | 291.5 | 323.8 | 345 | 15.968 | 27.79 | 87.99 | 86.00 |
| [d]1.000 | 5 | 17.89 | 365 | 309 | 337.9 | 354 | 16.023 | 26.53 | 82.64 | 81.64 |
| [e]1.000 | 7 | 17.86 | 376 | 296 | 334 | 336 | 14.991 | 22.61 | 75.84 | 74.64 |
| [f]1.000 | 5 | 17.82 | 369 | 325 | 348.6 | 356 | 16.723 | 28.52 | 85.59 | 84.35 |

20-INCH VICTOR, CYLINDER GATE.[a]

[Tested July 26, 1877, and February 21, 1878.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 2 | 18.17 | 266.5 | 246 | 256.2 | 266.5 | 22.914 | 38.02 | 83.63 | 77.77 |

25-INCH VICTOR, CYLINDER GATE.[a]

[Tested July 25, 1877, and March 26, 1878.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 2 | 18.02 | 209 | 200 | 204.5 | 209 | 38.092 | 62.72 | 85.84 | 80.58 |

30-INCH VICTOR, CYLINDER GATE.[a]

[Tested October 29, 1878.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 1 | 11.65 | 144.5 | 144.5 | 144.5 | 144.5 | 19.671 | 52.54 | 86.76 | 86.76 |

35-INCH VICTOR.[a]

[Tested September 5, 1879.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 9 | 17.11 | 156 | 126.6 | 142.5 | 150 | 83.32 | 132.46 | 83.34 | 82.04 |

30-INCH TYLER FLUME WHEEL, NO GATE.[g]

[Tested April, 1876.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 3 | 18.56 | 215 | 168 | 195.3 | 215.3 | 20.29 | 33.61 | 91.27 | 79.05 |

[a] Made by Stillwell & Bierce Manufacturing Company, Dayton, Ohio.
[b] Used in draft-tube experiments; tested in the ordinary way.
[c] With draft tube 23 inches in diameter and 10.33 feet long.
[d] With draft tube 19 inches in diameter and 10.33 feet long.
[e] With draft tube 15 inches in diameter and 10.33 feet long.
[f] With draft tube 21 inches in diameter, submerged 6.83 feet in backwater
[g] Made by John Tyler, Claremont, N. H.

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*Summary of James Emerson's tests of turbine water wheels*—Continued.

30-INCH TYLER, INSIDE REGISTER GATE.[a]

[Tested August 1, 1879.]

| Gate opening (proportional part). | Number of tests. | Mean head in feet. | Revolutions per minute. | | | | Mean discharge in second-feet. | Mean horsepower. | Percentage of efficiency. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Mean. | At maximum efficiency. | | | Maximum. | Mean. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1.000 | 8 | 18.27 | 218 | 180 | 201 | 198.5 | 23.32 | 38.60 | 82.25 | 80.01 |

42-INCH TYLER FLUME WHEEL, NO GATE.[a]

[Tested October 13, 1877.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 2 | 18.06 | 146.5 | 146 | 146.2 | 146.5 | 43.38 | 67.30 | 77.5 | 75.79 |

60-INCH TYLER, INSIDE REGISTER GATE.[a]

[Tested October 8, 1879.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 4 | 16.92 | 102.5 | 98 | 100.3 | 103 | 79.19 | 121.57 | 80.3 | 80.06 |

18-INCH LESNER, INSIDE REGISTER GATE.[b]

[Tested April 17, 1879.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 10 | 18.29 | 335.3 | 280 | 269.6 | 296 | 10.74 | 16.41 | 75.61 | 73.87 |

15-INCH HERCULES, CYLINDER GATE.[c]

[Tested March 5, 1880.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 6 | 17.9 | 375.5 | 298 | 342.7 | 356.5 | 18.03 | 29.44 | 82.94 | 81.87 |

33-INCH HERCULES, CYLINDER GATE.[c]

[Tested November 4–11, 1879; Runner of McCormick type; partial division plates.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 11 | 17.05 | 184.5 | 130 | 156.9 | 154.5 | 78.41 | 119.88 | 80.31 | 79.09 |
| 1.000 | 5 | 16.68 | 159.2 | 148.7 | 153.2 | 152 | 77.46 | 116.45 | 79.95 | 79.56 |

[a] Made by John Tyler, Claremont, N. H.
[b] Made by William B. Wemple Sons, Fultonville, N. Y.
[c] Made by Holyoke Machine Company, Holyoke, Mass.

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*Summary of James Emerson's tests of turbine water wheels*—Continued.

48-INCH HERCULES, CYLINDER GATE.[a]

[Tested January 10, 1880.]

| Gate opening (proportional part). | Number of tests. | Mean head in feet. | Revolutions per minute. | | | | Mean discharge in second-feet. | Mean horsepower. | Percentage of efficiency. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Mean. | At maximum efficiency. | | | Maximum. | Mean. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1.000 | 9 | 11.51 | 94.5 | 75.2 | 84.65 | 93.2 | 135.53 | 138.24 | 82.86 | 78.13 |
| .927 | 1 | 11.73 | 70.3 | 70.3 | 70.3 | 70.3 | 131.54 | 130.5 | 78.66 | 78.66 |
| .878 | 1 | 11.70 | 81.5 | 81.5 | 81.5 | 81.5 | 129.17 | 130.89 | 76.43 | 76.43 |
| .830 | 3 | 11.55 | 83.5 | 78.5 | 80.66 | 83.5 | 124.06 | 124.60 | 77.48 | 76.31 |
| .781 | 1 | 11.20 | 81.8 | 81.8 | 81.8 | 81.8 | 116.67 | 114.02 | 77 | 77 |
| .732 | 2 | 11.43 | 87 | 83.2 | 85.1 | 87 | 112.38 | 110.82 | 76.19 | 76.14 |
| .683 | 2 | 11.65 | 85.7 | 85 | 85.35 | 85.7 | 108.62 | 109.91 | 76.74 | 76.54 |
| .634 | 1 | 11.69 | 83 | 83 | 83 | 83 | 103.95 | 105.63 | 76.72 | 76.72 |
| .586 | 1 | 11.6 | 82.5 | 82.5 | 82.5 | 82.5 | 97.36 | 98.20 | 76.59 | 76.59 |
| .537 | 2 | 11.36 | 81 | 80 | 80.5 | 80 | 89.34 | 85.37 | 74.59 | 73.87 |
| .488 | 1 | 11 | 82 | 82 | 82 | 82 | 80.88 | 74.54 | 73.94 | 73.94 |
| .439 | 3 | 11.72 | 88.5 | 84 | 86 | 88.5 | 75.41 | 70.31 | 70.68 | 70.18 |

36-INCH HUNT.[b]

[Tested May 19, 1880.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 8 | 17.55 | 165 | 145.5 | 155.4 | 155.5 | 39.44 | 65.16 | 84.84 | 83.80 |
| 1.000 | 15 | 17.09 | 179 | 139.5 | 162.2 | 160 | 40.89 | 68.4 | 84.61 | 83.3 |

24-INCH REYNOLDS CHAMPION.[c]

[Tested October 13, 1879.]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 9 | 18.3 | 313 | 243.7 | 275.6 | 276.7 | 17.87 | 28.7 | 78.57 | 76.72 |

[a] Made by Holyoke Machine Company, Holyoke, Mass.
[b] Made by Rodney Hunt Machine Company, Orange, Mass.
[c] Made by Bloomer & Co., Ellenville, N. Y.

## TURBINE TESTS BY HOLYOKE WATER POWER COMPANY.

### GENERAL DISCUSSION.

The conditions under which turbines are tested at the Holyoke flume are described in the following circular issued by the Holyoke Water Power Company:

We are prepared to test turbines on vertical shaft, of any of the usual diameters (the pit is 20 feet square), and of any power up to 300 H. P.

The measuring weir has a capacity of about 230 cubic feet per second.

Small wheels may be tested under any head from 4 to 18 feet. Larger sizes, 11 to 14 feet.

The price of test and report is based on the amount of water drawn by the wheel when giving its best efficiency at full gate. But on account of variation of heads the quantity drawn will be computed for a head of 17 feet, and on that the charge will be 66⅔ cents per cubic foot per second, but no test for less than $30, the sender to pay freight and cartage.

Scroll wheels or wheels set in iron cases may cost $10 to $15 or more in addition.

A test will consist of five or six settings of the gate; additional settings will be charged extra.

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We can also test small and medium sizes, singly or in pairs, on horizontal shaft, under certain conditions, details of which will be sent on application. Price of horizontal test, from $50 up, depending on the amount of labor necessary to erect the wheel.

All results are kept strictly confidential, report being made only to the party ordering the test.

Duplicate reports, typewritten, or in India ink for blue printing, will be furnished at $2 each.

HOLYOKE WATER POWER COMPANY.

HOLYOKE, MASS., *November 1, 1898.*

The Holyoke flume serves three principal uses:

1. The testing of all wheels installed in conjunction with the water power at Holyoke, in order that their discharge capacity may be determined and used as a means of estimating the quantity of water taken by the several mills.

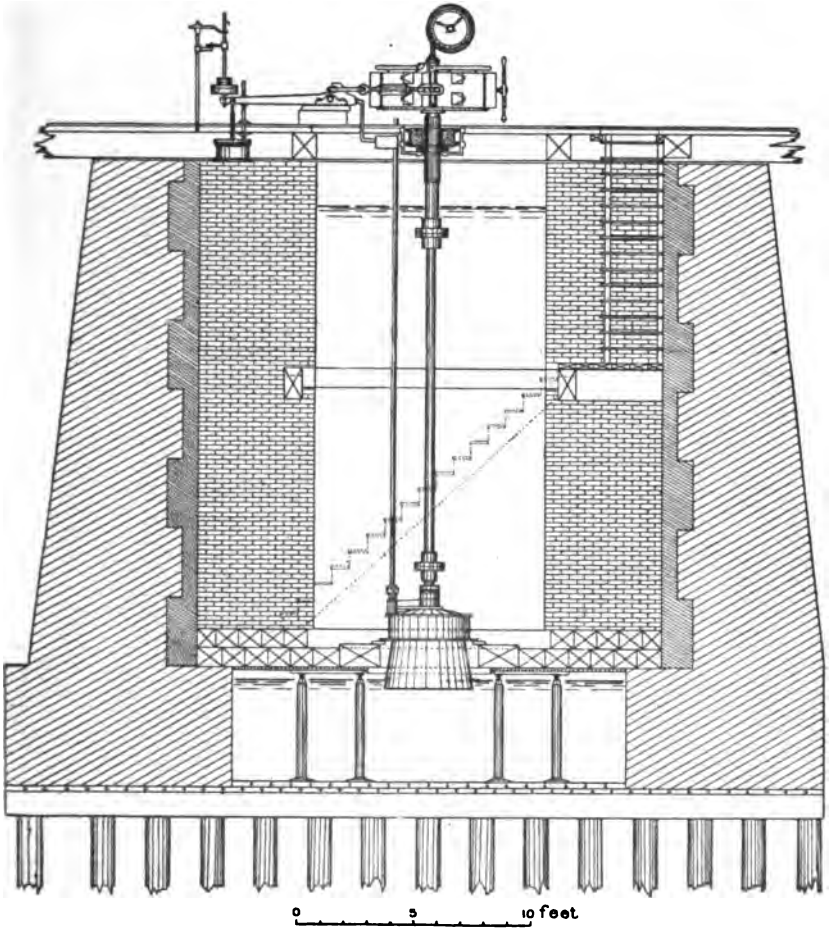


FIG. 14. Cross section of Holyoke testing flume.

2. The testing of experimental wheels with a view to their improvement. Many of the wheels tested, especially in the early years, have been of this class, and the results are of no general interest.

3. Testing of standard patterns of American type turbines which are to be installed in new plants. The results of such tests are of general and permanent interest.

A few complete tests have been published by Thurston[a] and in the catalogues of tur-

[a] Thurston, R. H., The systematic testing of turbine water wheels in the United States: Trans. Am. Soc. Mech. Eng., vol. 8, pp. 359–420.

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bine builders. The policy of the Holyoke Water Power Company has been to treat the results of the tests as the property of their clients, and they have never been made public without the permission of the parties for whom they were made. In the preparation of this paper application was first made to the Holyoke Water Power Company, and afterwards to a number of the leading turbine builders, for the results of Holyoke tests of standard patterns of wheels. As a result, complete reports of tests of a considerable number of turbines have been obtained for publication with the mutual consent of the Holyoke Water Power Company and the turbine builders.

Acknowledgment is due to Mr. A. F. Sickman, hydraulic engineer of the Holyoke Water Power Company, and to the Holyoke Machine Company, Worcester, Mass.; the S. Morgan Smith Company, York, Pa.; the James Leffel Company, Springfield, Ohio; J. & W. Jolly,

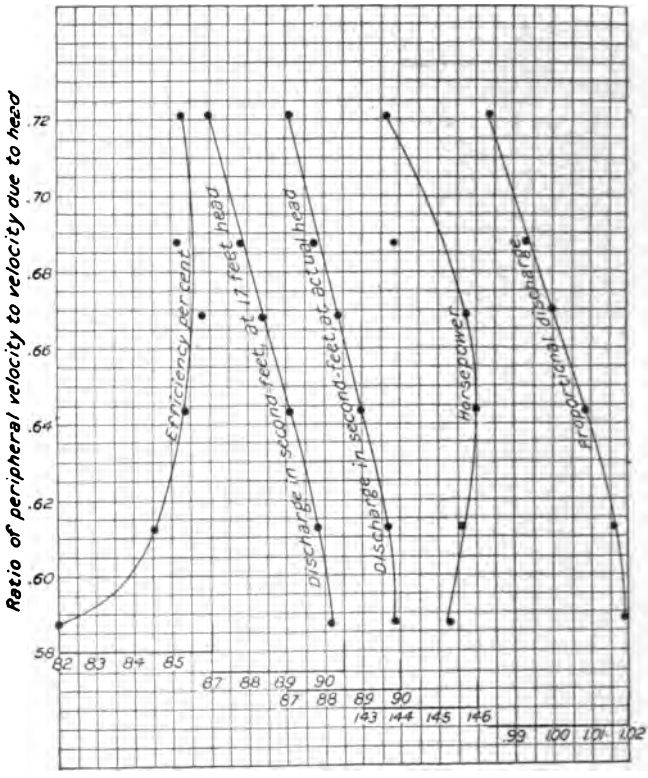


FIG. 15.—Log of test of 36-inch right-hand Hercules, full gate, test No.190, October 13, 1883.

Holyoke, Mass.; the Stillwell-Bierce and Smith-Vaile Company (now Platt Iron Works), Dayton, Ohio, and the Dayton Globe Iron Works, Dayton, Ohio.

The quantity of water used in the Holyoke tests (see tables, pp. 43–76) is determined by means of a thin-edged weir, with or without end contractions, according to the volume of flow. The discharge is computed by the Francis formula, and is given in column 7 of the tables. The power is determined by a friction dynamometer (see Pl. I, *B*), and is given in column 8 of the tables. Each wheel is tested under several positions of speed gate, commonly varying from about one-third to full gate. A varying number of tests at each gate is made, the load being so adjusted as to cover the ordinary range of speeds, both greater and less than that at which the maximum efficiency occurs. The net head acting on the wheel in feet is determined by means of hook gage readings, and is contained in column 4 of the tables. The measured gate opening, head, speed, discharge, and power constitute the basic data of the experiments. The efficiency for each experiment is computed from

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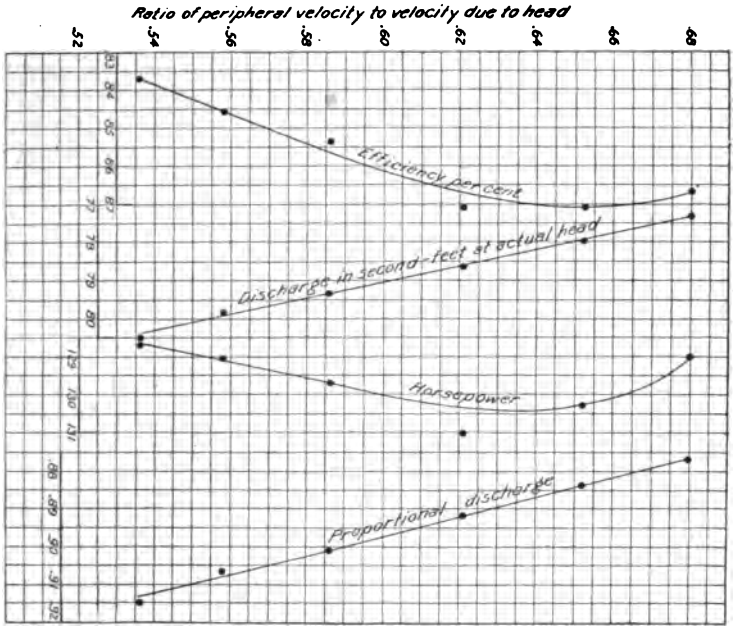


FIG. 16.—Log of test of 36-inch right-hand Hercules, 0.80 gate, test No. 190, October 13, 1883.

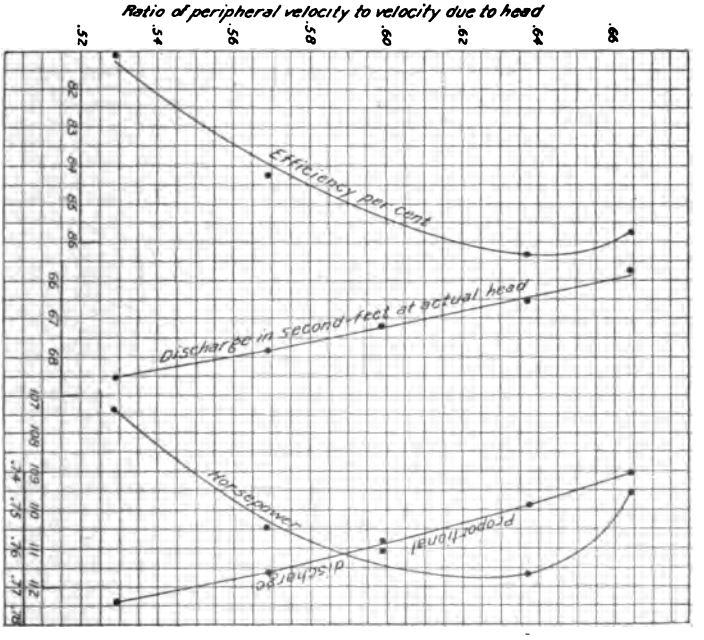


FIG. 17.—Log of test of 36-inch right-hand Hercules, 0.647 gate, test No. 190, October 13, 1883.

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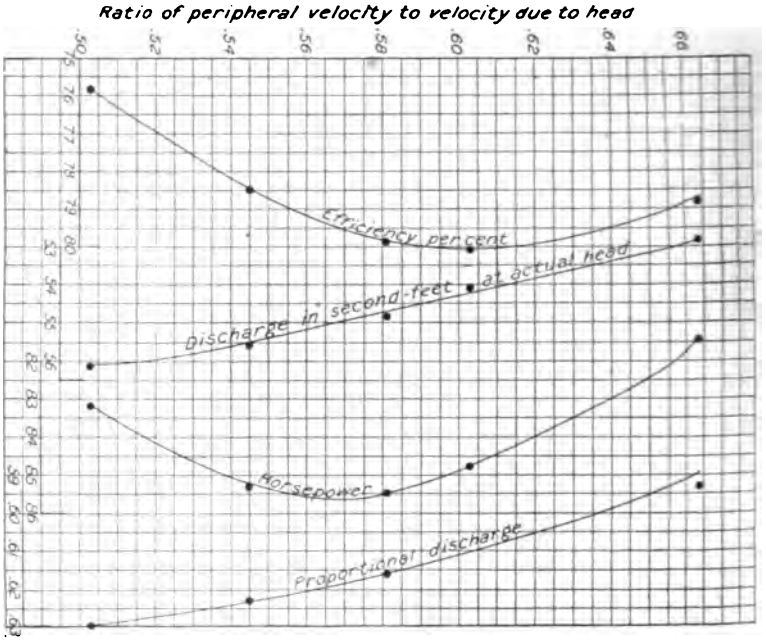


FIG. 18.—Log of test of 36-inch right-hand Hercules, 0.480 gate, test No.190, October 13, 1883.

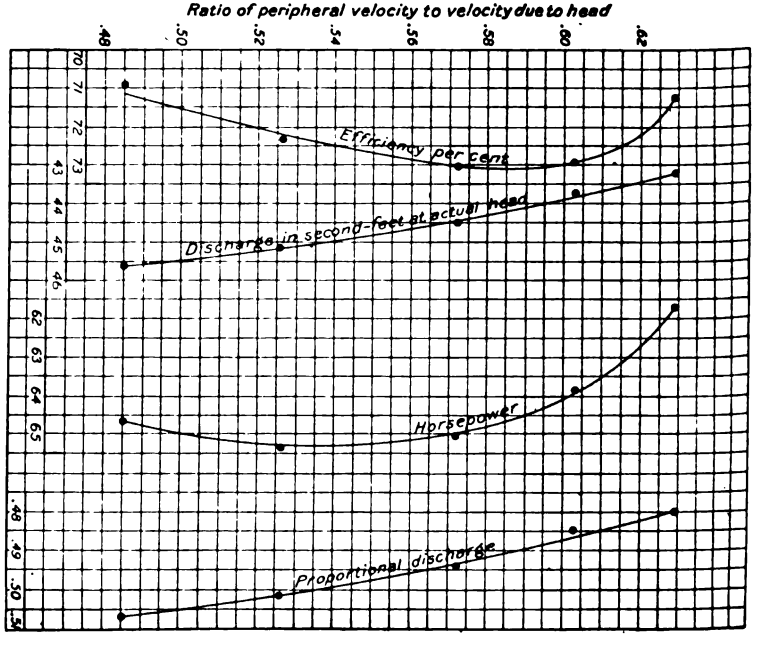


FIG. 19.—Log of test of 36-inch right-hand Hercules, 0.379 gate, test No.190, October 13, 1883.

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the measured discharge and power. This factor, together with the horsepower, is omitted from the series of tests of Smith-McCormick turbines.

In the reduction of the experiments, the ratio of the peripheral speed of the turbine to the spouting velocity due to the head is determined, and the data for each width of the gate opening are plotted, using as an argument the speed ratio described above. A series of curves is thus obtained for each gate opening showing the variation in the discharge, power, speed, and efficiency. A set of these curves for a 36-inch Hercules turbine is shown in figs. 15-19. From these diagrams the maximum efficiency for each width of gate opening and the speed at which it occurs may be easily determined.[a]

In column 3 of the tables of tests (pp. 43–76) is given the proportional part of the full-gate discharge, the unit discharge at full gate being that which occurs at the speed giving maximum efficiency under the head used in the experiments. The head and discharge corresponding to the highest efficiency having been determined from the full-gate test diagram, the proportional discharge is obtained as follows:

Let $H_e$ represent the head at which maximum full-gate efficiency was observed, and H any other head corresponding to a discharge Q at either full or part gate, then $Q' = \frac{\sqrt{H_e}}{\sqrt{H}} Q$ is approximately the discharge which would have resulted with the given gate opening

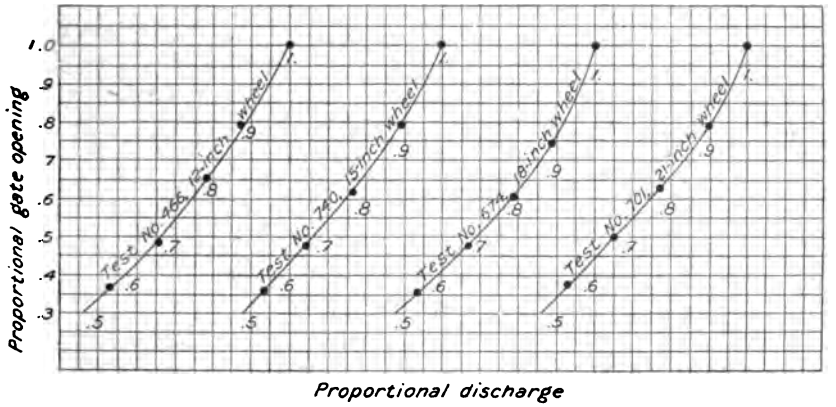


FIG. 20.—Proportional discharge coefficients for 12-, 15-, 18-, and 21-inch McCormick turbines.

under a head $H_e$ and the ratio of the quantity Q′ to the full-gate discharge at maximum efficiency $= \frac{Q'}{Q_e}$ is called the "proportional discharge" and is given in column 3. This column shows, therefore, the relative discharge at different gate openings all reduced to the head of maximum full-gate efficiency as a standard.

## DETAILED HOLYOKE TESTS.

### M'CORMICK TURBINES.

The McCormick turbine is notable for its great depth and capacity in proportion to its diameter. Many tests of all sizes have been made for the manufacturers, the S. Morgan Smith Company, York, Pa., and J. & W. Jolly, Holyoke, Mass. In the following tables will be found complete tests of all sizes from 12 to 57 inches diameter.

The mean factors for the group of experiments included in a single gate opening for a wheel of each size have been computed and are given in tabular form on pages 43–59. This data will enable any desired feature of the tests to be readily worked out for the different sizes. On figs. 20–23 are given the coefficients of part-gate discharge in form for ready comparison.

[a] The systematic testing of water wheels in the United States: Trans. Am. Soc. Mech. Eng., vol. 8, pp. 339-420.

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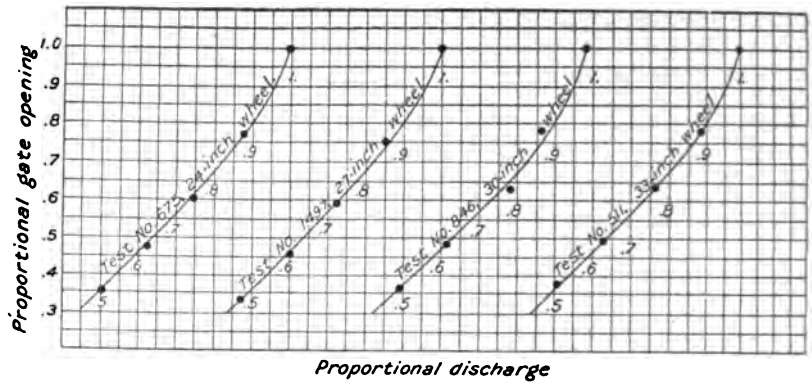


FIG. 21.—Proportional discharge coefficients for 24-, 27-, 30-, and 33-inch McCormick turbines.

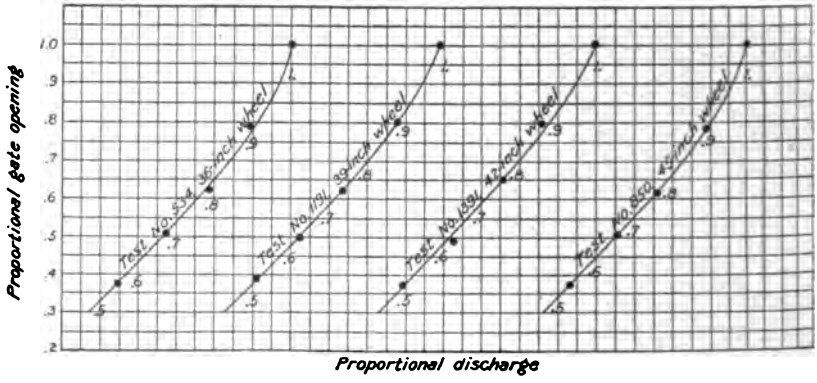


FIG. 22.—Proportional discharge coefficients for 36-, 39-, 42-, and 45-inch McCormick turbines.

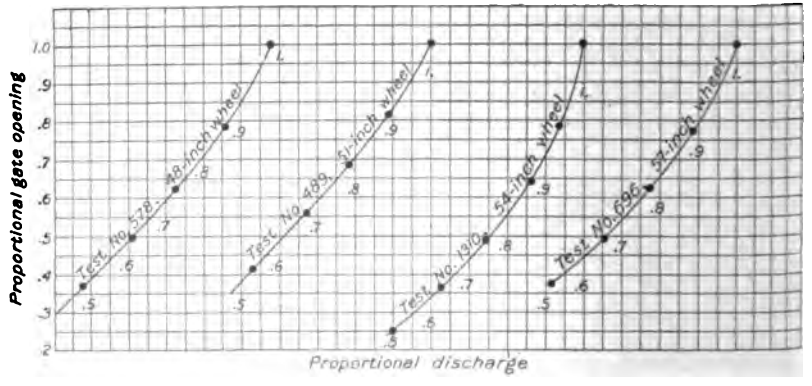


FIG. 23.—Proportional discharge coefficients for 48-, 51-, 54-, and 57-inch McCormick turbines.

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*Holyoke tests of McCormick turbines.*[a]

12-INCH RIGHT-HAND SMITH-McCORMICK WHEEL.

[Test No. 466, January 17, 1890.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency=1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | 1.000 | 1.013 | 17.92 | 5 | Still. | 11.35 |
| 9 | 1.000 | 1.019 | 17.84 | 4 | 375.0 | 11.39 |
| 8 | 1.000 | 1.010 | 17.85 | 5 | 395.0 | 11.29 |
| 7 | 1.000 | 1.009 | 17.80 | 4 | 406.7 | 11.27 |
| 6 | 1.000 | 1.000 | 18.00 | 4 | 424.7 | 11.23 |
| 5 | 1.000 | .995 | 18.01 | 4 | 437.7 | 11.18 |
| 4 | 1.000 | .991 | 18.02 | 4 | 449.0 | 11.13 |
| 3 | 1.000 | .985 | 18.09 | 4 | 464.5 | 11.09 |
| 2 | 1.000 | .979 | 17.98 | 6 | 477.8 | 10.99 |
| Mean | 1.000 | 1.000 | 17.945 | | 381.16 | |
| 22 | .799 | .895 | 17.90 | 4 | 361.0 | 10.02 |
| 21 | .799 | .889 | 17.87 | 4 | 388.5 | 9.95 |
| 20 | .799 | .882 | 17.87 | 3 | 407.0 | 9.87 |
| 19 | .799 | .875 | 17.85 | 3 | 421.3 | 9.79 |
| 18 | .799 | .870 | 17.86 | 4 | 435.7 | 9.73 |
| 17 | .799 | .864 | 17.89 | 5 | 451.8 | 9.67 |
| 16 | .799 | .860 | 17.91 | 3 | 476.0 | 9.63 |
| Mean | | .876 | 17.878 | | 420.1 | |
| 29 | .651 | .801 | 17.92 | 4 | 364.0 | 8.98 |
| 28 | .651 | .799 | 17.92 | 5 | 401.6 | 8.95 |
| 27 | .651 | .794 | 17.93 | 6 | 421.0 | 8.90 |
| 26 | .651 | .788 | 17.94 | 4 | 440.2 | 8.83 |
| 25 | .651 | .781 | 17.98 | 3 | 460.0 | 8.77 |
| 24 | .651 | .778 | 18.05 | 3 | 477.3 | 8.75 |
| 23 | .651 | .770 | 18.02 | 3 | 503.0 | 8.65 |
| Mean | | .787 | 17.965 | | 438.15 | |
| 33 | .488 | .667 | 18.06 | 4 | 362.0 | 7.50 |
| 32 | .488 | .662 | 18.08 | 3 | 392.0 | 7.45 |
| 31 | .488 | .660 | 18.02 | 4 | 415.0 | 7.42 |
| 30 | .488 | .656 | 18.04 | 4 | 439.5 | 7.38 |
| 34 | .488 | .651 | 18.07 | 4 | 462.0 | 7.32 |
| 35 | .488 | .644 | 18.07 | 6 | 479.5 | 7.25 |
| Mean | .488 | .656 | 18.056 | | 425.0 | |
| 15 | .369 | .541 | 18.35 | 3 | 346.0 | 6.13 |
| 14 | .369 | .539 | 18.12 | 4 | 366.0 | 6.07 |
| 13 | .369 | .537 | 18.12 | 4 | 392.2 | 6.05 |
| 12 | .369 | .531 | 18.10 | 4 | 417.5 | 5.98 |
| 11 | .369 | .524 | 18.14 | 3 | 440.7 | 5.91 |
| 10 | .369 | .520 | 18.23 | 4 | 477.0 | 5.88 |
| Mean | .369 | .532 | 18.176 | | 406.56 | |

[a] Made by S. Morgan Smith Company, York, Pa.

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*Holyoke tests of McCormick turbines*—Continued.

15-INCH LEFT-HAND McCORMICK HOLYOKE WHEEL.

[Test No. 740, March 20, 1894.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | 1.000 | 0.978 | 15.34 | 4 | Still. | 17.91 |
| 8 | 1.000 | 1.015 | 15.55 | 4 | 282.2 | 18.71 |
| 7 | 1.000 | 1.010 | 15.57 | 4 | 302.2 | 18.64 |
| 6 | 1.000 | 1.007 | 15.59 | 4 | 321.7 | 18.59 |
| 5 | 1.000 | 1.003 | 15.61 | 4 | 333.5 | 18.52 |
| 4 | 1.000 | 1.000 | 15.63 | 5 | 354.0 | 18.48 |
| 3 | 1.000 | .993 | 15.65 | 5 | 372.0 | 18.37 |
| 2 | 1.000 | .992 | 15.27 | 5 | 375.8 | 18.12 |
| Mean | 1.000 | .999 | 15.526 | | 377.34 | 15.536 |
| 15 | .791 | .910 | 15.80 | 4 | 284.7 | 16.91 |
| 14 | .791 | .904 | 15.80 | 3 | 306.7 | 16.80 |
| 13 | .791 | .900 | 15.75 | 5 | 326.2 | 16.69 |
| 12 | .791 | .893 | 15.75 | 4 | 340.0 | 16.61 |
| 11 | .791 | .891 | 15.77 | 5 | 353.0 | 16.54 |
| 10 | .791 | .883 | 15.79 | 4 | 372.2 | 16.40 |
| 9 | .791 | .869 | 15.81 | 4 | 395.7 | 16.16 |
| Mean | .791 | .893 | 15.781 | | 339.78 | |
| 24 | .615 | .780 | 16.15 | 3 | 270.0 | 14.66 |
| 23 | .615 | .779 | 16.13 | 4 | 293.2 | 14.63 |
| 22 | .615 | .775 | 16.12 | 5 | 307.0 | 14.55 |
| 21 | .615 | .772 | 16.08 | 5 | 323.2 | 14.47 |
| 20 | .615 | .767 | 16.09 | 4 | 338.2 | 14.39 |
| 19 | .615 | .760 | 16.09 | 4 | 352.7 | 14.26 |
| 18 | .615 | .755 | 16.08 | 4 | 365.5 | 14.16 |
| 17 | .615 | .750 | 16.08 | 4 | 377.7 | 14.06 |
| 16 | .615 | .745 | 16.08 | 4 | 389.0 | 13.96 |
| Mean | .615 | .765 | 16.10 | | 335.17 | |
| 32 | .475 | .654 | 16.26 | 4 | 267.5 | 12.32 |
| 31 | .475 | .651 | 16.29 | 3 | 292.0 | 12.29 |
| 30 | .475 | .648 | 16.30 | 4 | 310.0 | 12.24 |
| 29 | .475 | .644 | 16.35 | 4 | 327.5 | 12.17 |
| 28 | .475 | .639 | 16.37 | 4 | 342.5 | 12.09 |
| 27 | .475 | .636 | 16.41 | 4 | 358.0 | 12.04 |
| 26 | .475 | .632 | 16.43 | 4 | 372.7 | 11.97 |
| 25 | .475 | .627 | 16.41 | 4 | 395.5 | 11.88 |
| Mean | .475 | .641 | 16.35 | | 333.21 | |
| 39 | .359 | .539 | 16.37 | 4 | 268.2 | 10.20 |
| 38 | .359 | .539 | 16.38 | 4 | 291.5 | 10.20 |
| 37 | .359 | .535 | 16.39 | 4 | 313.0 | 10.12 |
| 36 | .359 | .533 | 16.40 | 4 | 328.5 | 10.09 |
| 35 | .359 | .527 | 16.42 | 4 | 348.0 | 9.99 |
| 34 | .359 | .523 | 16.43 | 4 | 365.7 | 9.92 |
| 33 | .359 | .520 | 16.44 | 4 | 382.2 | 9.85 |
| Mean | .359 | .531 | 16.40 | | 328.16 | |

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*Holyoke tests of McCormick turbines*—Continued.

18-INCH LEFT-HAND SMITH-McCORMICK WHEEL.

[Test No. 674, April 18, 1893.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | 1.000 | 1.071 | 17.37 | 5 | Still. | 27.57 |
| 6 | 1.000 | 1.020 | 17.41 | 4 | 235.5 | 26.28 |
| 5 | 1.000 | 1.012 | 17.41 | 4 | 248.0 | 26.07 |
| 4 | 1.000 | 1.005 | 17.43 | 4 | 258.7 | 25.92 |
| 3 | 1.000 | .999 | 17.45 | 4 | 271.2 | 25.76 |
| 2 | 1.000 | .990 | 17.48 | 4 | 286.0 | 25.55 |
| 7 | 1.000 | .980 | 17.42 | 4 | 299.7 | 25.27 |
| Mean | 1.000 | 1.011 | 17.424 | | 228.44 | |
| 13 | .748 | .904 | 17.44 | 5 | 227.8 | 23.30 |
| 12 | .748 | .899 | 17.47 | 5 | 243.0 | 23.20 |
| 11 | .748 | .892 | 17.46 | 6 | 259.0 | 23.01 |
| 10 | .748 | .888 | 17.50 | 4 | 266.0 | 22.95 |
| 9 | .748 | .883 | 17.48 | 4 | 274.7 | 22.80 |
| 8 | .748 | .872 | 17.52 | 4 | 292.0 | 22.55 |
| Mean | .748 | .889 | 17.478 | | 260.42 | |
| 19 | .604 | .797 | 17.68 | 4 | 234.0 | 20.70 |
| 18 | .604 | .794 | 17.65 | 4 | 245.2 | 20.60 |
| 17 | .604 | .792 | 17.63 | 5 | 257.2 | 20.54 |
| 16 | .604 | .789 | 17.63 | 5 | 266.4 | 20.45 |
| 15 | .604 | .783 | 17.61 | 5 | 272.5 | 20.30 |
| 14 | .604 | .779 | 17.56 | 6 | 281.6 | 20.16 |
| Mean | .604 | .789 | 17.626 | | 259.48 | |
| 23 | .476 | .673 | 17.65 | 5 | 215.5 | 17.47 |
| 27 | .476 | .675 | 17.73 | 3 | 227.7 | 17.54 |
| 22 | .476 | .672 | 17.59 | 10 | 230.0 | 17.41 |
| 26 | .476 | .672 | 17.68 | 4 | 243.0 | 17.45 |
| 21 | .476 | .672 | 17.50 | 4 | 246.5 | 17.36 |
| 25 | .476 | .668 | 17.69 | 4 | 256.2 | 17.36 |
| 20 | .476 | .668 | 17.40 | 4 | 256.2 | 17.21 |
| 24 | .476 | .663 | 17.69 | 4 | 273.5 | 17.21 |
| Mean | .476 | .670 | 17.616 | | 243.57 | |
| 28 | .356 | .540 | 17.82 | 4 | 195.5 | 14.08 |
| 29 | .356 | .539 | 17.79 | 4 | 214.2 | 14.05 |
| 30 | .356 | .538 | 17.79 | 4 | 233.2 | 14.01 |
| 31 | .356 | .536 | 17.79 | 4 | 250.2 | 13.96 |
| 32 | .356 | .533 | 17.87 | 4 | 267.0 | 13.92 |
| 33 | .356 | .531 | 17.84 | 4 | 279.2 | 13.85 |
| Mean | .356 | .536 | 17.816 | | 239.88 | |

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*Holyoke tests of McCormick turbines*—Continued.

21-INCH LEFT-HAND McCORMICK HOLYOKE WHEEL.

[Test No. 701, August 17, 1893.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 1.000 | 1.024 | 15.66 | 4 | 205.7 | 35.40 |
| 7 | 1.000 | 1.018 | 15.62 | 4 | 214.5 | 35.15 |
| 6 | 1.000 | 1.013 | 15.62 | 4 | 224.0 | 34.95 |
| 5 | 1.000 | 1.006 | 15.65 | 4 | 234.2 | 34.76 |
| 4 | 1.000 | 1.000 | 15.66 | 4 | 244.0 | 34.55 |
| 3 | 1.000 | .993 | 15.68 | 4 | 253.7 | 34.32 |
| 2 | 1.000 | .983 | 15.71 | 4 | 266.7 | 34.02 |
| 1 | 1.000 | .972 | 15.75 | 4 | 280.0 | 33.69 |
| Mean | 1.000 | 1.001 | 15.869 | | 240.35 | |
| 15 | .790 | .914 | 15.79 | 4 | 194.2 | 31.73 |
| 14 | .790 | .911 | 15.81 | 4 | 210.0 | 31.63 |
| 13 | .790 | .904 | 15.82 | 4 | 222.0 | 31.39 |
| 12 | .790 | .899 | 15.83 | 4 | 233.2 | 31.22 |
| 11 | .790 | .893 | 15.85 | 4 | 244.0 | 31.03 |
| 10 | .790 | .886 | 15.89 | 4 | 255.5 | 30.85 |
| 9 | .790 | .874 | 15.90 | 4 | 271.5 | 30.45 |
| Mean | .790 | .897 | 15.841 | | 232.91 | |
| 21 | .628 | .780 | 15.58 | 4 | 190.0 | 26.88 |
| 20 | .628 | .781 | 15.60 | 5 | 209.4 | 26.96 |
| 19 | .628 | .776 | 15.63 | 5 | 225.0 | 26.79 |
| 18 | .628 | .772 | 15.67 | 4 | 237.5 | 26.67 |
| 17 | .628 | .768 | 15.71 | 4 | 248.0 | 26.57 |
| 16 | .628 | .763 | 15.73 | 5 | 258.4 | 26.43 |
| 22 | .628 | .756 | 15.68 | 4 | 265.0 | 26.15 |
| Mean | .628 | .711 | 15.157 | | 233.33 | |
| 29 | .499 | .652 | 15.79 | 4 | 192.2 | 22.64 |
| 28 | .499 | .655 | 15.82 | 4 | 211.0 | 22.75 |
| 27 | .499 | .656 | 15.77 | 4 | 223.0 | 22.75 |
| 26 | .499 | .654 | 15.76 | 4 | 230.6 | 22.67 |
| 25 | .499 | .653 | 15.76 | 4 | 239.7 | 22.64 |
| 24 | .499 | .648 | 15.81 | 4 | 252.2 | 22.49 |
| 23 | .499 | .642 | 15.87 | 4 | 263.5 | 22.35 |
| Mean | .499 | .651 | 15.797 | | 230.31 | |
| 36 | .374 | .534 | 15.69 | 4 | 186.2 | 18.46 |
| 35 | .374 | .535 | 15.70 | 4 | 205.7 | 18.50 |
| 34 | .374 | .533 | 15.70 | 4 | 217.2 | 18.44 |
| 33 | .374 | .531 | 15.74 | 4 | 227.0 | 18.41 |
| 32 | .374 | .529 | 15.74 | 3 | 235.0 | 18.33 |
| 31 | .374 | .526 | 15.77 | 4 | 245.0 | 18.25 |
| 30 | .374 | .522 | 15.82 | 4 | 256.2 | 18.14 |
| Mean | .374 | .530 | 15.737 | | 224.61 | |

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*Holyoke tests of McCormick turbines*—Continued.

24-INCH LEFT-HAND SMITH-McCORMICK WHEEL.

[Test No. 675, April 19, 1893.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 39 | 1.000 | 1.012 | 16.83 | 4 | 178.25 | 47.88 |
| 38 | 1.000 | 1.009 | 16.84 | 3 | 186.33 | 47.74 |
| 37 | 1.000 | 1.005 | 16.83 | 4 | 195.25 | 47.55 |
| 36 | 1.000 | 1.002 | 16.82 | 4 | 203.50 | 47.41 |
| 35 | 1.000 | .999 | 16.84 | 4 | 210.00 | 47.27 |
| 34 | 1.000 | .995 | 16.86 | 4 | 216.50 | 47.13 |
| 33 | 1.000 | .992 | 16.88 | 4 | 222.25 | 46.99 |
| 32 | 1.000 | .984 | 16.94 | 4 | 232.00 | 46.71 |
| Mean | 1.000 | .999 | 16.855 | ..... | 228.44 | ..... |
| 31 | .771 | .894 | 17.13 | 4 | 179.00 | 42.65 |
| 30 | .771 | .891 | 17.14 | 4 | 189.25 | 42.55 |
| 29 | .771 | .887 | 17.25 | 4 | 199.75 | 42.47 |
| 28 | .771 | .882 | 17.24 | 4 | 207.75 | 42.25 |
| 27 | .771 | .879 | 17.29 | 4 | 215.00 | 42.16 |
| 26 | .771 | .875 | 17.30 | 4 | 221.50 | 41.95 |
| 25 | .771 | .869 | 17.32 | 4 | 228.75 | 41.73 |
| 24 | .771 | .861 | 17.33 | 4 | 240.00 | 41.34 |
| Mean | .771 | .879 | 17.250 | ..... | 210.12 | ..... |
| 23 | .604 | .765 | 17.47 | 4 | 183.00 | 36.87 |
| 22 | .604 | .761 | 17.49 | 4 | 191.75 | 36.68 |
| 21 | .604 | .756 | 17.49 | 5 | 202.00 | 36.46 |
| 20 | .604 | .750 | 17.47 | 4 | 209.75 | 36.16 |
| 19 | .604 | .744 | 17.47 | 5 | 218.00 | 35.86 |
| 18 | .604 | .739 | 17.43 | 4 | 224.75 | 35.56 |
| 17 | .604 | .726 | 17.44 | 4 | 236.50 | 34.98 |
| Mean | .604 | .749 | 17.465 | ..... | 209.39 | ..... |
| 16 | 0.471 | .643 | 17.47 | 4 | 176.00 | 30.98 |
| 15 | .471 | .639 | 17.44 | 4 | 186.00 | 30.77 |
| 14 | .471 | .635 | 17.47 | 4 | 195.00 | 30.61 |
| 13 | .471 | .630 | 17.45 | 4 | 202.75 | 30.36 |
| 12 | .471 | .625 | 17.47 | 4 | 211.50 | 30.12 |
| 11 | .471 | .618 | 17.48 | 4 | 220.25 | 29.80 |
| 10 | .471 | .611 | 17.52 | 4 | 229.50 | 29.48 |
| 9 | .471 | .601 | 17.53 | 4 | 240.25 | 29.03 |
| Mean | .471 | .625 | 17.478 | ..... | 207.65 | ..... |
| 8 | .358 | .519 | 17.58 | 4 | 169.25 | 23.11 |
| 7 | .358 | .518 | 17.54 | 4 | 179.00 | 25.01 |
| 6 | .358 | .513 | 17.54 | 4 | 191.25 | 24.80 |
| 5 | .358 | .507 | 17.51 | 4 | 200.75 | 24.49 |
| 4 | .358 | .504 | 17.48 | 4 | 209.00 | 24.28 |
| 3 | .358 | .497 | 17.42 | 4 | 219.50 | 23.93 |
| 2 | .358 | .491 | 17.45 | 4 | 230.50 | 23.67 |
| 1 | .358 | .487 | 17.46 | 4 | 238.25 | 23.47 |
| Mean | .358 | .504 | 17.497 | ..... | 204.69 | ..... |

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*Holyoke tests of McCormick turbines*—Continued.

27-INCH RIGHT-HAND SMITH-McCORMICK WHEEL, CONICAL CYLINDER.

[Test No. 1497, December 14, 1903.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 7 | 1.000 | 1.011 | 17.79 | 3 | 168.00 | 60.32 |
| 6 | 1.000 | 1.008 | 17.78 | 4 | 178.50 | 60.13 |
| 5 | 1.000 | 1.007 | 17.78 | 4 | 186.50 | 60.07 |
| 4 | 1.000 | 1.005 | 17.78 | 4 | 194.75 | 60.00 |
| 3 | 1.000 | 1.003 | 17.80 | 4 | 203.25 | 59.87 |
| 2 | 1.000 | 1.000 | 17.78 | 5 | 213.00 | 59.66 |
| 1 | 1.000 | .992 | 17.80 | 4 | 231.25 | 59.20 |
| Mean | 1.000 | 1.003 | 17.787 | | 196.46 | |
| 15 | .754 | .872 | 17.95 | 4 | 163.50 | 52.30 |
| 14 | .754 | .871 | 17.96 | 4 | 174.00 | 52.24 |
| 13 | .754 | .865 | 17.95 | 4 | 185.25 | 51.89 |
| 12 | .754 | .858 | 17.97 | 4 | 190.75 | 51.45 |
| 11 | .754 | .853 | 17.98 | 4 | 198.50 | 51.21 |
| 10 | .754 | .848 | 17.98 | 4 | 206.50 | 50.90 |
| 9 | .754 | .840 | 17.99 | 4 | 216.25 | 50.40 |
| 8 | .754 | .829 | 17.99 | 4 | 225.50 | 49.78 |
| Mean | | .854 | 17.971 | | 195.03 | |
| 22 | .591 | .740 | 18.08 | 4 | 160.50 | 44.51 |
| 21 | .591 | .741 | 18.08 | 4 | 173.75 | 44.56 |
| 20 | .591 | .737 | 18.10 | 4 | 184.00 | 44.39 |
| 19 | .591 | .730 | 18.11 | 4 | 191.25 | 43.95 |
| 18 | .591 | .723 | 18.12 | 4 | 199.25 | 43.58 |
| 17 | .591 | .712 | 18.16 | 4 | 210.00 | 42.91 |
| 16 | .591 | .700 | 18.16 | 4 | 223.00 | 42.19 |
| Mean | .591 | .726 | 18.116 | | 191.67 | |
| 28 | .456 | .609 | 18.22 | 4 | 164.00 | 36.80 |
| 27 | .456 | .610 | 18.23 | 4 | 175.00 | 36.86 |
| 26 | .456 | .608 | 18.23 | 4 | 183.50 | 36.74 |
| 25 | .456 | .602 | 18.25 | 4 | 190.25 | 36.40 |
| 24 | .456 | .596 | 18.26 | 4 | 200.00 | 36.06 |
| 23 | .456 | .589 | 18.28 | 4 | 211.75 | 35.65 |
| Mean | | .602 | 18.245 | | 187.42 | |
| 33 | .334 | .481 | 18.39 | 4 | 161.25 | 29.21 |
| 32 | .334 | .480 | 18.39 | 4 | 171.50 | 29.14 |
| 31 | .334 | .476 | 18.41 | 4 | 180.00 | 28.90 |
| 30 | .334 | .473 | 18.40 | 4 | 187.25 | 28.73 |
| 29 | .334 | .470 | 18.41 | 4 | 195.00 | 28.53 |
| 34 | .334 | .464 | 18.42 | 5 | 210.00 | 28.18 |
| Mean | .334 | .474 | 18.043 | | 184.17 | |

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*Holyoke tests of McCormick turbines*—Continued.

30-INCH RIGHT-HAND SMITH-McCORMICK WHEEL.

[Test No. 846, May 10, 1895.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 15 | 1,000 | 1.007 | 16.73 | 4 | 146.00 | 75.06 |
| 15 | 1,000 | 1.006 | 16.73 | 4 | 156.00 | 72.99 |
| 14 | 1,000 | 1.002 | 16.71 | 4 | 168.50 | 72.71 |
| 13 | 1,000 | .993 | 16.73 | 5 | 169.30 | 72.06 |
| 11 | 1,000 | .974 | 16.74 | 4 | 176.50 | 76.71 |
| 10 | 1,000 | .976 | 16.78 | 4 | 188.50 | 70.28 |
| 9 | 1,000 | .959 | 16.81 | 4 | 193.95 | 69.79 |
| 8 | 1,000 | .942 | 16.89 | 4 | 207.75 | 68.71 |
| Mean | 1,000 | .981 | 16.76 | ..... | 177.58 | ..... |
| 24 | .783 | .896 | 17.11 | 4 | 143.30 | 64.32 |
| 23 | .783 | .881 | 17.08 | 4 | 154.50 | 64.59 |
| 22 | .783 | .874 | 17.18 | 4 | 161.75 | 64.32 |
| 21 | .783 | .868 | 17.19 | 5 | 167.00 | 63.89 |
| 20 | .783 | .863 | 17.14 | 4 | 174.00 | 63.37 |
| 19 | .783 | .855 | 17.08 | 4 | 185.25 | 62.71 |
| 18 | .783 | .847 | 17.03 | 4 | 186.25 | 62.05 |
| 17 | .783 | .830 | 17.06 | 3 | 188.67 | 60.84 |
| Mean | .783 | .864 | 17.10 | ..... | 170.08 | ..... |
| 30 | .630 | .757 | 17.34 | 4 | 155.50 | 65.96 |
| 29 | .630 | .757 | 17.37 | 4 | 153.00 | 56.02 |
| 28 | .630 | .755 | 17.37 | 4 | 168.75 | 55.32 |
| 27 | .630 | .751 | 17.33 | 4 | 173.86 | 55.43 |
| 26 | .630 | .744 | 17.34 | 4 | 178.75 | 54.95 |
| 25 | .630 | .736 | 17.41 | 4 | 187.00 | 54.24 |
| Mean | .630 | .750 | 17.36 | ... ... ... | 169.64 | ..... |
| 38 | .489 | .622 | 17.54 | 4 | 144.25 | 46.25 |
| 37 | .489 | .624 | 17.53 | 4 | 151.25 | 46.37 |
| 36 | .489 | .624 | 17.53 | 3 | 158.67 | 46.37 |
| 35 | .489 | .623 | 17.53 | 4 | 166.00 | 46.32 |
| 34 | .489 | .620 | 17.55 | 4 | 171.25 | 46.12 |
| 33 | .489 | .615 | 17.54 | 4 | 177.50 | 45.74 |
| 32 | .489 | .608 | 17.56 | 4 | 185.25 | 45.24 |
| 31 | .489 | .589 | 17.58 | 4 | 198.50 | 44.56 |
| Mean | .489 | .616 | 17.55 | ..... | 169.08 | ..... |
| 7 | .369 | .495 | 17.60 | 4 | 132.75 | 36.94 |
| 6 | .369 | .498 | 17.62 | 3 | 142.33 | 37.12 |
| 5 | .369 | .498 | 17.61 | 3 | 149.33 | 37.12 |
| 4 | .369 | .498 | 17.57 | 3 | 159.00 | 37.07 |
| 3 | .369 | .492 | 17.63 | 4 | 172.00 | 36.72 |
| 2 | .369 | .488 | 17.60 | 3 | 179.33 | 36.33 |
| 1 | .369 | .481 | 17.59 | 4 | 190.50 | 35.81 |
| Mean | .369 | .493 | 17.602 | ..... | 160.748 | ..... |



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*Holyoke tests of McCormick turbines*—Continued.

SPECIAL 33-INCH LEFT-HAND IMPROVED SMITH-McCORMICK WHEEL.

[Test No. 511, January 29–30, 1891.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 46 | 1.000 | 0.998 | 15.37 | 4 | 141.50 | 83.77 |
| 45 | 1.000 | .992 | 15.42 | 4 | 149.75 | 83.33 |
| 44 | 1.000 | .982 | 15.31 | 3 | 156.00 | 82.26 |
| 42 | 1.000 | 1.003 | 13.11 | 3 | 128.00 | 77.70 |
| 43 | 1.000 | 1.000 | 13.13 | 3 | 133.00 | 77.55 |
| 41 | 1.000 | .994 | 13.17 | 4 | 137.75 | 77.19 |
| 40 | 1.000 | 1.014 | 11.27 | 4 | 112.75 | 72.83 |
| 39 | 1.000 | 1.010 | 11.30 | 3 | 116.75 | 72.69 |
| 38 | 1.000 | 1.007 | 11.32 | 4 | 121.00 | 72.48 |
| 37 | 1.000 | 1.003 | 11.36 | 5 | 126.00 | 72.34 |
| 36 | 1.000 | .993 | 11.40 | 5 | 132.20 | 71.78 |
| 35 | 1.000 | .982 | 11.45 | 3 | 140.00 | 71.13 |
| Mean | 1.000 | .998 | 12.80 | ..... | 132.89 | ..... |
| 34 | .783 | .900 | 11.48 | 4 | 115.00 | 65.23 |
| 33 | .783 | .897 | 11.51 | 5 | 120.00 | 65.09 |
| 32 | .783 | .891 | 11.55 | 4 | 124.00 | 64.79 |
| 31 | .783 | .885 | 11.55 | 4 | 130.00 | 64.36 |
| 30 | .783 | .876 | 11.61 | 4 | 136.00 | 63.84 |
| 29 | .783 | .864 | 11.66 | 4 | 144.25 | 63.15 |
| Mean | ..... | .885 | 11.56 | ..... | 128.21 | ..... |
| 27 | .634 | .784 | 11.59 | 4 | 115.00 | 57.10 |
| 26 | .634 | .776 | 11.64 | 4 | 121.00 | 56.69 |
| 25 | .634 | .769 | 11.67 | 4 | 127.75 | 56.20 |
| 24 | .634 | .756 | 11.73 | 4 | 135.00 | 55.38 |
| 28 | .634 | .742 | 11.79 | 4 | 142.00 | 54.34 |
| Mean | .634 | .632 | 13.25 | ..... | 135.25 | ..... |
| 22 | .493 | .646 | 13.21 | 4 | 120.50 | 50.24 |
| 21 | .493 | .641 | 13.21 | 4 | 127.50 | 50.03 |
| 20 | .493 | .635 | 13.23 | 4 | 132.50 | 49.46 |
| 19 | .493 | .629 | 13.25 | 3 | 138.00 | 48.97 |
| 18 | .493 | .623 | 13.28 | 4 | 143.00 | 48.60 |
| 17 | .493 | .616 | 13.33 | 3 | 150.00 | 48.16 |
| Mean | .493 | .632 | 13.252 | ..... | 135.26 | ..... |
| 16 | .377 | .526 | 12.55 | 4 | 105.25 | 39.98 |
| 15 | .377 | .524 | 12.54 | 3 | 112.00 | 39.70 |
| 14 | .377 | .519 | 12.54 | 4 | 118.00 | 39.36 |
| 13 | .377 | .517 | 12.55 | 4 | 122.00 | 39.19 |
| 12 | .377 | .510 | 12.57 | 4 | 128.00 | 38.68 |
| 11 | .377 | .506 | 12.60 | 4 | 133.75 | 38.40 |
| 10 | .377 | .499 | 12.63 | 4 | 139.75 | 37.94 |
| 9 | .377 | .491 | 12.68 | 4 | 148.25 | 37.43 |
| 8 | .377 | .484 | 12.72 | 3 | 155.33 | 36.92 |
| Mean | .377 | .508 | 12.598 | ..... | 129.15 | ..... |

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*Holyoke tests of McCormick turbines*—Continued.

36-INCH LEFT-HAND McCORMICK HOLYOKE WHEEL.

[Test No. 534, June 13, 1891.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 6 | 1.000 | 1.026 | 16.83 | 4 | 119.75 | 103.93 |
| 5 | 1.000 | 1.019 | 16.81 | 4 | 125.00 | 103.30 |
| 4 | 1.000 | 1.015 | 16.83 | 4 | 131.00 | 102.94 |
| 3 | 1.000 | 1.008 | 16.83 | 4 | 137.00 | 102.25 |
| 2 | 1.000 | 1.003 | 16.74 | 4 | 142.25 | 101.42 |
| 7 | 1.000 | .995 | 16.84 | 5 | 149.20 | 100.96 |
| 1 | 1.000 | .986 | 16.81 | 3 | 155.67 | 99.91 |
| Mean | 1,000 | 1.007 | 16.81 | ..... | 137.15 | ..... |
| 14 | .789 | .919 | 16.99 | 4 | 118.25 | 93.61 |
| 13 | .789 | .917 | 16.99 | 4 | 125.50 | 93.40 |
| 12 | .789 | .912 | 17.00 | 4 | 132.50 | 92.93 |
| 11 | .789 | .907 | 17.01 | 4 | 139.25 | 92.49 |
| 10 | .789 | .900 | 17.05 | 4 | 145.75 | 91.80 |
| 9 | .789 | .892 | 17.07 | 4 | 152.50 | 91.13 |
| 8 | .789 | .885 | 17.06 | 4 | 158.50 | 90.34 |
| Mean | .789 | .894 | 17.024 | ..... | 138.89 | ..... |
| 20 | .629 | .799 | 17.28 | 4 | 118.50 | 82.10 |
| 19 | .629 | .797 | 17.30 | 4 | 128.00 | 81.89 |
| 18 | .629 | .793 | 17.29 | 4 | 134.75 | 81.46 |
| 17 | .629 | .787 | 17.30 | 4 | 140.75 | 80.90 |
| 16 | .629 | .781 | 17.32 | 4 | 146.50 | 80.37 |
| 15 | .629 | .773 | 17.31 | 4 | 152.50 | 79.49 |
| Mean | .629 | .788 | 17.300 | ..... | 135.17 | ..... |
| 27 | .502 | .681 | 17.58 | 4 | 115.75 | 70.59 |
| 26 | .502 | .681 | 17.60 | 3 | 124.00 | 70.59 |
| 25 | .502 | .677 | 17.59 | 4 | 131.75 | 70.19 |
| 24 | .502 | .675 | 17.61 | 4 | 138.75 | 69.97 |
| 23 | .502 | .672 | 17.60 | 4 | 141.50 | 69.67 |
| 22 | .502 | .664 | 17.61 | 3 | 147.00 | 68.84 |
| 21 | .502 | .656 | 17.65 | 5 | 153.60 | 68.12 |
| Mean | .502 | .672 | 17.605 | ..... | 135.76 | ..... |
| 34 | .379 | .554 | 17.82 | 4 | 110.75 | 57.78 |
| 33 | .379 | .553 | 17.81 | 5 | 118.80 | 57.68 |
| 32 | .379 | .551 | 17.80 | 4 | 126.75 | 57.48 |
| 31 | .379 | .550 | 17.83 | 4 | 134.75 | 57.39 |
| 30 | .379 | .545 | 17.81 | 4 | 141.50 | 57.83 |
| 29 | .379 | .539 | 17.81 | 3 | 148.33 | 56.26 |
| 28 | .379 | .533 | 17.82 | 3 | 156.67 | 55.58 |
| Mean | .379 | .546 | 17.814 | ..... | 133.94 | ..... |

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*Holyoke tests of McCormick turbines*—Continued.

39-INCH LEFT-HAND SMITH-McCORMICK WHEEL.

[Test No. 1191, May 29, 1899.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 1.000 | 1.009 | 15.79 | 1 | 126.00 | 117.8 |
| 7 | 1.000 | 1.006 | 15.79 | 4 | 131.75 | 117.4 |
| 6 | 1.000 | 1.001 | 15.82 | 4 | 138.00 | 116.9 |
| 5 | 1.000 | .998 | 15.85 | 4 | 143.00 | 116.7 |
| 4 | 1.000 | .990 | 15.87 | 4 | 150.00 | 115.9 |
| 3 | 1.000 | .977 | 15.91 | 5 | 154.60 | 114.5 |
| 2 | 1.000 | .961 | 15.96 | 4 | 160.25 | 112.9 |
| 1 | 1.000 | .945 | 15.98 | 4 | 165.75 | 110.9 |
| Mean | 1.000 | .986 | 15.871 | | 148.17 | |
| 43 | .796 | .903 | 15.95 | 4 | 118.25 | 105.9 |
| 42 | .796 | .899 | 15.97 | 4 | 123.75 | 105.5 |
| 41 | .796 | .893 | 15.97 | 4 | 128.25 | 105.0 |
| 40 | .796 | .888 | 15.99 | 4 | 133.00 | 104.4 |
| 39 | .796 | .882 | 15.99 | 5 | 136.60 | 103.6 |
| 38 | .796 | .874 | 16.03 | 4 | 140.50 | 102.7 |
| 37 | .796 | .864 | 16.08 | 4 | 145.00 | 101.7 |
| 36 | .796 | .853 | 16.06 | 4 | 149.00 | 100.4 |
| 35 | .796 | .843 | 16.11 | 4 | 153.25 | 99.0 |
| Mean | .796 | .876 | 16.018 | | 136.51 | |
| 34 | .621 | .760 | 16.26 | 4 | 123.75 | 89.9 |
| 33 | .621 | .754 | 16.29 | 4 | 127.25 | 89.4 |
| 32 | .621 | .748 | 16.29 | 5 | 130.80 | 88.7 |
| 31 | .621 | .742 | 16.30 | 4 | 134.00 | 87.9 |
| 30 | .621 | .734 | 16.34 | 4 | 138.25 | 87.1 |
| 29 | .621 | .728 | 16.35 | 4 | 142.25 | 86.5 |
| 28 | .621 | .716 | 16.37 | 4 | 147.75 | 85.0 |
| 27 | .621 | .703 | 16.40 | 4 | 156.25 | 83.6 |
| Mean | .621 | .736 | 16.575 | | 137.54 | |
| 26 | .498 | .645 | 16.55 | 3 | 115.00 | 77.1 |
| 25 | .498 | .640 | 16.55 | 4 | 120.25 | 76.6 |
| 24 | .498 | .636 | 16.55 | 5 | 123.60 | 75.9 |
| 23 | .498 | .630 | 16.56 | 4 | 127.75 | 75.3 |
| 22 | .498 | .625 | 16.59 | 4 | 131.75 | 74.7 |
| 21 | .498 | .619 | 16.60 | 4 | 136.25 | 74.1 |
| 20 | .498 | .611 | 16.69 | 4 | 143.00 | 73.3 |
| 19 | .498 | .600 | 16.71 | 4 | 150.25 | 72.0 |
| 18 | .498 | .588 | 16.78 | 4 | 157.75 | 70.7 |
| Mean | .498 | .621 | 16.620 | | 133.95 | |

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*Holyoke tests of McCormick turbines*—Continued.

39-INCH LEFT-HAND SMITH-McCORMICK WHEEL—Continued.

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 17 | 0.390 | 0.527 | 16.72 | 4 | 116.75 | 63.25 |
| 16 | .390 | .522 | 16.73 | 4 | 121.50 | 62.66 |
| 15 | .390 | .516 | 16.75 | 4 | 125.50 | 62.06 |
| 14 | .390 | .512 | 16.78 | 4 | 129.50 | 61.66 |
| 13 | .390 | .509 | 16.77 | 4 | 133.00 | 61.28 |
| 12 | .390 | .506 | 16.76 | 4 | 135.50 | 60.86 |
| 11 | .390 | .502 | 16.75 | 4 | 139.75 | 60.38 |
| 10 | .390 | .495 | 16.77 | 4 | 145.00 | 59.60 |
| 9 | .390 | .489 | 16.77 | 5 | 150.60 | 58.81 |
| Mean | .390 | .509 | 16.757 | | 133.01 | |

42-INCH LEFT-HAND SMITH-McCORMICK WHEEL.

[Test No. 1391, March 19, 1902.]

| | | | | | | |
|---|---|---|---|---|---|---|
| 43 | 1.000 | 1.002 | 16.32 | 4 | 121.50 | 148.20 |
| 42 | 1.000 | 1.002 | 16.06 | 5 | 123.40 | 147.02 |
| 41 | 1.000 | 1.002 | 16.02 | 4 | 128.00 | 146.85 |
| 44 | 1.000 | 1.000 | 16.34 | 4 | 135.00 | 147.94 |
| 40 | 1.000 | 1.001 | 16.05 | 4 | 135.20 | 146.73 |
| 39 | 1.000 | .986 | 16.19 | 4 | 141.00 | 145.14 |
| 38 | 1.000 | .970 | 16.28 | 4 | 146.50 | 143.27 |
| Mean | 1.000 | .995 | 16.180 | | 132.94 | |
| 37 | .794 | .886 | 16.56 | 4 | 110.25 | 131.89 |
| 36 | .794 | .882 | 16.59 | 5 | 116.80 | 131.50 |
| 35 | .794 | .876 | 16.64 | 4 | 120.50 | 130.73 |
| 34 | .794 | .865 | 16.68 | 4 | 125.00 | 129.34 |
| 33 | .794 | .856 | 16.71 | 4 | 128.75 | 128.07 |
| 32 | .794 | .845 | 16.79 | 5 | 133.80 | 126.68 |
| 31 | .794 | .832 | 16.85 | 4 | 138.50 | 125.02 |
| 30 | .794 | .819 | 16.93 | 4 | 144.00 | 123.28 |
| Mean | .794 | .858 | 16.718 | | 127.20 | |
| 28 | .648 | .770 | 16.96 | 4 | 103.00 | 116.11 |
| 27 | .648 | .775 | 16.94 | 4 | 111.00 | 116.70 |
| 29 | .648 | .771 | 16.94 | 5 | 114.20 | 116.21 |
| 26 | .648 | .770 | 16.96 | 4 | 118.00 | 116.11 |
| 25 | .648 | .762 | 16.97 | 4 | 121.50 | 114.90 |
| 24 | .648 | .754 | 17.01 | 4 | 125.00 | 113.80 |
| 23 | .648 | .743 | 17.03 | 4 | 129.50 | 112.22 |
| 22 | .648 | .737 | 17.04 | 4 | 133.75 | 111.33 |
| 21 | .648 | .725 | 17.11 | 4 | 139.75 | 109.77 |
| 20 | .648 | .716 | 17.12 | 4 | 145.00 | 108.46 |
| Mean | .648 | .752 | 17.000 | | 124.07 | |

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*Holyoke tests of McCormick turbines*—Continued.

42-INCH LEFT-HAND SMITH-McCORMICK WHEEL—Continued.

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 19 | 0.497 | 0.642 | 17.34 | 2 | 102.00 | 97.81 |
| 18 | .497 | .645 | 17.30 | 4 | 108.50 | 98.15 |
| 17 | .497 | .643 | 17.29 | 4 | 114.25 | 97.91 |
| 16 | .497 | .639 | 17.30 | 4 | 118.00 | 97.21 |
| 15 | .497 | .634 | 17.25 | 4 | 121.00 | 96.31 |
| 14 | .497 | .628 | 17.25 | 4 | 124.50 | 95.52 |
| 13 | .497 | .625 | 17.10 | 5 | 127.00 | 94.61 |
| 12 | .497 | .619 | 17.13 | 4 | 132.00 | 93.80 |
| 11 | .497 | .616 | 17.19 | 4 | 137.00 | 93.46 |
| 10 | .497 | .608 | 17.29 | 4 | 142.75 | 92.55 |
| 9 | .497 | .600 | 17.38 | 4 | 149.50 | 91.56 |
| Mean | .497 | .627 | 17.257 | | 125.14 | |
| 8 | .375 | .504 | 17.67 | 4 | 92.62 | 77.53 |
| 7 | .375 | .505 | 17.73 | 4 | 100.00 | 77.85 |
| 6 | .375 | .507 | 17.81 | 4 | 108.25 | 78.28 |
| 5 | .375 | .505 | 17.80 | 4 | 116.50 | 77.95 |
| 4 | .375 | .500 | 17.82 | 5 | 123.40 | 77.21 |
| 3 | .375 | .495 | 17.75 | 5 | 129.00 | 76.27 |
| 2 | .375 | .489 | 17.74 | 5 | 137.00 | 75.40 |
| 1 | .375 | .484 | 17.64 | 4 | 144.25 | 74.46 |
| Mean | .375 | .498 | 17.745 | | 118.88 | |

45-INCH RIGHT-HAND SPECIAL McCORMICK-HOLYOKE WHEEL.

[Test No. 850, June 10, 1895.]

| | | | | | | |
|---|---|---|---|---|---|---|
| 10 | 1.000 | 1.031 | 16.37 | 4 | 100.50 | 112.94 |
| 9 | 1.000 | 1.025 | 16.41 | 4 | 104.87 | 112.43 |
| 8 | 1.000 | 1.019 | 16.46 | 4 | 109.50 | 111.96 |
| 7 | 1.000 | 1.013 | 16.50 | 5 | 114.00 | 111.35 |
| 6 | 1.000 | 1.007 | 16.23 | 4 | 116.00 | 109.78 |
| 5 | 1.000 | 1.000 | 16.23 | 4 | 120.37 | 109.05 |
| 4 | 1.000 | .994 | 16.23 | 4 | 124.50 | 108.43 |
| 3 | 1.000 | .987 | 16.28 | 4 | 129.50 | 107.85 |
| 2 | 1.000 | .978 | 16.31 | 5 | 134.80 | 106.91 |
| 1 | 1.000 | .966 | 16.37 | 4 | 141.50 | 105.84 |
| Mean | 1.000 | 1.002 | 16.339 | | 119.55 | |
| 18 | .783 | .913 | 16.63 | 4 | 96.00 | 100.80 |
| 17 | .783 | .906 | 16.64 | 4 | 101.50 | 100.09 |
| 16 | .783 | .899 | 16.67 | 4 | 106.75 | 99.40 |
| 15 | .783 | 894 | 16.68 | 4 | 111.50 | 98.83 |
| 14 | .783 | .888 | 16.67 | 4 | 115.50 | 98.14 |
| 13 | .783 | .882 | 16.67 | 4 | 120.00 | 97.46 |
| 12 | .783 | .875 | 16.65 | 4 | 125.50 | 96.67 |
| 11 | .783 | .866 | 16.68 | 4 | 132.00 | 95.74 |
| Mean | .783 | .890 | 16.661 | | 113.59 | |

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*Holyoke tests of McCormick turbines*—Continued.

45-INCH RIGHT-HAND SPECIAL McCORMICK-HOLYOKE WHEEL—Continued.

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 25 | 0.612 | 0.777 | 17.16 | 4 | 97.25 | 87.17 |
| 24 | .612 | .771 | 17.17 | 4 | 103.00 | 86.51 |
| 23 | .612 | .765 | 17.18 | 4 | 108.75 | 85.85 |
| 22 | .612 | .758 | 17.17 | 4 | 113.75 | 85.08 |
| 21 | .612 | .751 | 17.14 | 4 | 118.75 | 84.21 |
| 20 | .612 | .746 | 16.97 | 4 | 122.75 | 83.22 |
| 19 | .612 | .735 | 17.00 | 4 | 129.50 | 82.02 |
| Mean | .612 | .757 | 17.112 | ..... | 113.39 | ..... |
| 33 | .503 | .676 | 17.29 | 4 | 95.00 | 76.15 |
| 32 | .503 | .672 | 17.30 | 4 | 101.25 | 75.62 |
| 31 | .503 | .665 | 17.31 | 4 | 107.00 | 74.88 |
| 30 | .503 | .658 | 17.34 | 4 | 113.50 | 74.13 |
| 29 | .503 | .651 | 17.36 | 4 | 118.50 | 73.40 |
| 28 | .503 | .643 | 17.38 | 4 | 123.75 | 72.56 |
| 27 | .503 | .633 | 17.39 | 5 | 130.00 | 71.41 |
| 26 | .503 | .620 | 17.41 | 4 | 137.75 | 69.99 |
| Mean | .503 | .652 | 17.347 | ..... | 115.84 | ..... |
| 41 | .373 | .548 | 17.56 | 4 | 93.00 | 62.15 |
| 40 | .373 | .545 | 17.54 | 4 | 98.25 | 61.76 |
| 39 | .373 | .540 | 17.59 | 4 | 104.50 | 61.35 |
| 38 | .373 | .535 | 17.59 | 4 | 109.75 | 60.75 |
| 37 | .373 | .531 | 17.53 | 4 | 115.25 | 60.18 |
| 36 | .373 | .526 | 17.54 | 4 | 120.00 | 59.69 |
| 35 | .373 | .520 | 17.55 | 4 | 125.00 | 59.00 |
| 34 | .373 | .511 | 17.57 | 3 | 131.00 | 58.03 |
| Mean | .373 | .532 | 17.558 | ..... | 112.09 | ..... |

48-INCH LEFT-HAND SMITH-McCORMICK WHEEL.

[Test No. 578, April 5, 1892.]

| | | | | | | |
|---|---|---|---|---|---|---|
| 54 | 1.000 | 1.017 | 12.99 | 5 | 78.70 | 157.07 |
| 53 | 1.000 | 1.008 | 13.03 | 4 | 83.50 | 155.97 |
| 52 | 1.000 | 1.000 | 13.06 | 4 | 89.00 | 154.87 |
| 51 | 1.000 | .991 | 13.13 | 5 | 93.70 | 153.80 |
| 50 | 1.000 | .983 | 12.96 | 4 | 95.75 | 151.65 |
| 49 | 1.000 | .973 | 13.01 | 5 | 100.00 | 150.35 |
| 48 | 1.000 | .960 | 13.09 | 4 | 104.00 | 148.80 |
| 47 | 1.000 | .948 | 13.16 | 4 | 108.37 | 147.35 |
| 46 | 1.000 | .935 | 13.22 | 4 | 111.75 | 145.63 |
| Mean | 1.000 | .979 | 13.072 | ..... | 96.08 | ..... |

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*Holyoke tests of McCormick turbines*—Continued.

48-INCH LEFT-HAND SMITH-McCORMICK WHEEL—Continued.

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 38 | 0.780 | 0.895 | 13.10 | 4 | 75.62 | 138.80 |
| 37 | .780 | .887 | 13.10 | 4 | 80.12 | 137.55 |
| 36 | .780 | .882 | 13.09 | 4 | 84.62 | 136.75 |
| 35 | .780 | .875 | 13.05 | 5 | 88.00 | 135.45 |
| 34 | .780 | .868 | 13.08 | 4 | 91.75 | 134.55 |
| 33 | .780 | .860 | 13.16 | 4 | 96.50 | 133.65 |
| 32 | .780 | .849 | 13.23 | 4 | 100.50 | 132.35 |
| 31 | .780 | .839 | 13.31 | 4 | 105.00 | 131.16 |
| 30 | .780 | .831 | 13.10 | 4 | 107.25 | 128.90 |
| 29 | .780 | .820 | 13.20 | 3 | 111.00 | 127.65 |
| Mean | .780 | .860 | 13.142 | | 94.03 | |
| 28 | .621 | .764 | 13.90 | 4 | 78.25 | 122.05 |
| 27 | .621 | .758 | 13.93 | 4 | 82.75 | 121.17 |
| 26 | .621 | .751 | 13.97 | 4 | 87.37 | 120.31 |
| 25 | .621 | .743 | 14.00 | 4 | 91.75 | 119.17 |
| 24 | .621 | .737 | 14.00 | 4 | 95.50 | 118.16 |
| 23 | .621 | .727 | 14.03 | 4 | 99.50 | 116.70 |
| 22 | .621 | .717 | 14.08 | 4 | 103.50 | 115.35 |
| 21 | .621 | .707 | 14.10 | 4 | 107.37 | 113.75 |
| 20 | .621 | .696 | 14.17 | 5 | 110.90 | 112.20 |
| 19 | .621 | .688 | 14.19 | 4 | 114.25 | 111.05 |
| Mean | .621 | .728 | 14.039 | | 97.11 | |
| 18 | .499 | .638 | 14.09 | 4 | 82.00 | 102.55 |
| 17 | .499 | .633 | 14.10 | 4 | 85.50 | 101.85 |
| 16 | .499 | .626 | 14.11 | 4 | 89.50 | 100.80 |
| 15 | .499 | .620 | 14.13 | 4 | 93.50 | 99.85 |
| 14 | .499 | .613 | 14.15 | 4 | 97.62 | 98.73 |
| 13 | .499 | .605 | 14.19 | 4 | 101.87 | 97.67 |
| 12 | .499 | .595 | 14.27 | 4 | 106.75 | 96.28 |
| 11 | .499 | .584 | 14.35 | 4 | 111.37 | 94.85 |
| 10 | .499 | .575 | 14.40 | 5 | 116.10 | 93.58 |
| Mean | .499 | .609 | 14.198 | | 98.24 | |
| 9 | .371 | .504 | 13.68 | 4 | 76.00 | 79.89 |
| 8 | .371 | .498 | 13.70 | 4 | 81.00 | 79.05 |
| 7 | .371 | .494 | 13.74 | 4 | 85.37 | 78.40 |
| 6 | .371 | .488 | 13.78 | 4 | 89.87 | 77.65 |
| 5 | .371 | .484 | 13.83 | 4 | 93.50 | 77.05 |
| 4 | .371 | .477 | 13.88 | 4 | 99.00 | 76.08 |
| 3 | .371 | .469 | 13.93 | 4 | 104.62 | 74.95 |
| 2 | .371 | .461 | 13.98 | 4 | 110.12 | 73.79 |
| 1 | .371 | .453 | 14.03 | 4 | 115.50 | 72.75 |
| Mean | .371 | .480 | 13.838 | | 94.99 | |

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*Holyoke tests of McCormick turbines*—Continued.

51-INCH LEFT-HAND McCORMICK WHEEL.

[Test No. 489, June 28, 1890.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency=1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 35 | 1.000 | 1.026 | 11.49 | 3 | 68.67 | 169.60 |
| 34 | 1.000 | 1.021 | 11.52 | 3 | 72.50 | 169.05 |
| 33 | 1.000 | 1.016 | 11.53 | 4 | 76.50 | 168.35 |
| 32 | 1.000 | 1.009 | 11.58 | 6 | 80.50 | 167.50 |
| 31 | 1.000 | 1.001 | 11.62 | 3 | 84.50 | 166.50 |
| 30 | 1.000 | .989 | 11.68 | 4 | 88.62 | 164.95 |
| 29 | 1.000 | .979 | 11.74 | 3 | 92.17 | 163.60 |
| Mean | 1.000 | 1.005 | 10.165 | ..... | 80.49 | ..... |
| 8 | .818 | .915 | 12.88 | 3 | 74.00 | 160.18 |
| 7 | .818 | .910 | 12.91 | 2 | 78.25 | 159.50 |
| 6 | .818 | .902 | 12.96 | 3 | 83.17 | 158.40 |
| 5 | .818 | .895 | 12.99 | 4 | 87.62 | 157.32 |
| 4 | .818 | .887 | 13.02 | 4 | 92.00 | 156.10 |
| 3 | .818 | .880 | 12.84 | 4 | 94.00 | 155.89 |
| 2 | .818 | .870 | 12.91 | 3 | 98.67 | 152.45 |
| 1 | .818 | .850 | 13.09 | 5 | 105.10 | 150.05 |
| Mean | .818 | .888 | 12.950 | ..... | 89.10 | ..... |
| 28 | .685 | .808 | 13.09 | 4 | 71.62 | 142.70 |
| 27 | .685 | .803 | 13.11 | 4 | 77.75 | 141.78 |
| 26 | .685 | .797 | 13.09 | 4 | 83.00 | 140.72 |
| 25 | .685 | .790 | 13.10 | 4 | 87.25 | 139.42 |
| 24 | .685 | .782 | 13.10 | 4 | 92.00 | 138.01 |
| 23 | .685 | .768 | 13.18 | 4 | 97.25 | 136.10 |
| 22 | .685 | .753 | 13.29 | 3 | 102.00 | 133.90 |
| Mean | .685 | .785 | 13.137 | ..... | 87.26 | ..... |
| 21 | .554 | .693 | 13.25 | 3 | 71.00 | 123.10 |
| 20 | .554 | .688 | 13.26 | 4 | 76.75 | 122.30 |
| 19 | .554 | .684 | 13.14 | 5 | 82.00 | 120.92 |
| 18 | .554 | .677 | 13.17 | 4 | 88.00 | 119.80 |
| 17 | .554 | .666 | 13.25 | 4 | 93.00 | 118.28 |
| 16 | .554 | .656 | 13.31 | 4 | 97.75 | 116.69 |
| 15 | .554 | .641 | 13.44 | 4 | 105.50 | 114.60 |
| Mean | .554 | .672 | 13.260 | ..... | 87.71 | ..... |
| 14 | .414 | .549 | 13.92 | 4 | 71.62 | 99.90 |
| 13 | .414 | .546 | 13.91 | 4 | 78.75 | 99.30 |
| 12 | .414 | .542 | 13.93 | 4 | 84.25 | 98.72 |
| 11 | .414 | .537 | 13.91 | 4 | 89.50 | 97.70 |
| 10 | .414 | .529 | 13.95 | 4 | 95.50 | 96.45 |
| 9 | .414 | .521 | 13.99 | 4 | 101.25 | 95.05 |
| Mean | .414 | .537 | 13.935 | ..... | 86.81 | ..... |

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*Holyoke tests of McCormick turbines*—Continued.

54-INCH RIGHT-HAND SMITH-McCORMICK WHEEL, PLAIN CYLINDER GATE.[a]

[Test No. 1310, December 10–11, 1900.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 26 | 1.000 | 1.015 | 14.00 | 4 | 80.87 | 227.98 |
| 25 | 1.000 | 1.007 | 14.27 | 4 | 87.75 | 228.28 |
| 24 | 1.000 | 1.003 | 14.51 | 4 | 94.50 | 229.34 |
| 23 | 1.000 | .997 | 14.54 | 4 | 98.25 | 228.28 |
| 22 | 1.000 | .994 | 14.46 | 4 | 101.25 | 226.91 |
| 21 | 1.000 | .981 | 14.54 | 4 | 109.87 | 224.60 |
| Mean | 1.000 | .999 | 14.586 | | 95.41 | |
| 35 | .783 | .939 | 14.66 | 4 | 92.25 | 215.80 |
| 34 | .783 | .936 | 14.74 | 4 | 97.75 | 215.64 |
| 33 | .783 | .930 | 14.90 | 4 | 102.62 | 215.48 |
| 36 | .783 | .927 | 14.58 | 4 | 104.87 | 212.43 |
| Mean | .783 | .933 | 14.720 | | 99.37 | |
| 31 | .643 | .872 | 15.19 | 3 | 86.50 | 204.04 |
| 30 | .643 | .869 | 15.21 | 4 | 91.37 | 203.44 |
| 29 | .643 | .865 | 15.36 | 4 | 96.87 | 203.44 |
| 32 | .643 | .862 | 15.25 | 4 | 98.50 | 202.10 |
| 28 | .643 | .858 | 15.42 | 4 | 103.50 | 202.36 |
| 27 | .643 | .850 | 15.53 | 3 | 109.67 | 201.03 |
| Mean | .643 | .862 | 15.326 | | 97.73 | |
| 13 | .490 | .759 | 14.09 | 4 | 80.50 | 171.00 |
| 12 | .490 | .755 | 14.54 | 4 | 89.37 | 172.85 |
| 11 | .490 | .750 | 14.90 | 6 | 96.00 | 173.84 |
| 10 | .490 | .739 | 15.22 | 4 | 101.25 | 173.11 |
| 9 | .490 | .729 | 15.32 | 4 | 105.75 | 171.40 |
| Mean | .490 | .746 | 14.814 | | 94.57 | |
| 16 | .366 | .646 | 16.12 | 4 | 83.75 | 155.59 |
| 5 | .366 | .642 | 16.22 | 3 | 91.00 | 155.20 |
| 4 | .366 | .638 | 16.21 | 3 | 96.50 | 154.10 |
| 3 | .366 | .630 | 16.22 | 3 | 100.12 | 152.20 |
| 2 | .366 | .621 | 16.26 | 4 | 105.37 | 150.21 |
| 1 | .366 | .600 | 16.35 | 4 | 116.50 | 145.80 |
| Mean | .366 | .629 | 16.062 | | 97.20 | |
| 19 | .250 | .517 | 16.33 | 4 | 74.25 | 125.40 |
| 18 | .250 | .516 | 16.37 | 5 | 79.40 | 125.40 |
| 17 | .250 | .515 | 16.29 | 4 | 84.50 | 124.67 |
| 20 | .250 | .512 | 16.30 | 4 | 87.75 | 124.15 |
| 16 | .250 | .510 | 16.33 | 4 | 91.00 | 123.79 |
| 15 | .250 | .505 | 16.02 | 4 | 93.50 | 121.40 |
| 14 | .250 | .502 | 15.80 | 4 | 97.00 | 119.79 |
| Mean | .250 | .500 | 16.205 | | 86.77 | |

[a] Tested on conical draft tube manufactured by S. Morgan Smith Company.

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*Holyoke tests of McCormick turbines*—Continued.

57-INCH McCORMICK-HOLYOKE WHEEL.

[Test No. 696, August 7, 1893.

| Number of experiment. | Gate opening (proportional part). | Proportional discharges. (Discharge at full gate with highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 31 | 1.000 | 1.020 | 9.32 | 5 | 60.20 | 200.67 |
| 30 | 1.000 | 1.015 | 9.27 | 4 | 62.87 | 199.18 |
| 29 | 1.000 | 1.006 | 9.25 | 4 | 65.37 | 197.23 |
| 28 | 1.000 | .999 | 9.20 | 5 | 68.00 | 195.28 |
| 27 | 1.000 | .992 | 9.16 | 4 | 70.50 | 193.48 |
| 26 | 1.000 | .987 | 9.05 | 4 | 72.50 | 191.28 |
| Mean | 1.000 | 1.003 | 9.208 | ..... | 66.57 | ..... |
| 25 | .780 | .903 | 9.89 | 4 | 62.62 | 182.98 |
| 24 | .780 | .894 | 9.98 | 4 | 66.75 | 182.03 |
| 23 | .780 | .885 | 10.04 | 4 | 70.50 | 180.73 |
| 22 | .780 | .876 | 10.05 | 4 | 73.62 | 179.45 |
| 21 | .780 | .876 | 10.04 | 4 | 75.25 | 178.86 |
| 20 | .780 | .866 | 10.14 | 4 | 78.25 | 177.72 |
| Mean | .780 | .883 | 10.023 | ..... | 71.16 | ..... |
| 19 | .629 | .789 | 10.83 | 4 | 63.25 | 167.31 |
| 18 | .629 | .784 | 10.86 | 4 | 67.50 | 166.48 |
| 17 | .629 | .779 | 10.90 | 4 | 71.12 | 165.67 |
| 16 | .629 | .768 | 10.98 | 4 | 75.62 | 164.04 |
| 15 | .629 | .757 | 11.07 | 4 | 79.25 | 162.29 |
| 14 | .629 | .744 | 11.16 | 3 | 82.67 | 160.09 |
| Mean | .629 | .770 | 10.966 | ..... | 73.23 | ..... |
| 13 | .493 | .669 | 11.13 | 4 | 61.62 | 143.74 |
| 12 | .493 | .662 | 11.20 | 5 | 65.90 | 142.82 |
| 11 | .493 | .657 | 11.22 | 4 | 70.37 | 141.92 |
| 10 | .493 | .649 | 11.30 | 4 | 74.12 | 140.59 |
| 9 | .493 | .641 | 11.34 | 4 | 77.62 | 139.03 |
| 8 | .493 | .630 | 11.42 | 5 | 82.00 | 137.12 |
| Mean | .493 | .651 | 11.268 | ..... | 71.80 | ..... |
| 7 | .376 | .537 | 11.42 | 4 | 61.37 | 117.01 |
| 6 | .376 | .534 | 11.45 | 4 | 66.25 | 116.39 |
| 5 | .376 | .527 | 11.52 | 4 | 70.87 | 115.18 |
| 4 | .376 | .519 | 11.61 | 4 | 75.50 | 113.93 |
| 3 | .376 | .512 | 11.67 | 4 | 79.87 | 112.72 |
| 2 | .376 | .503 | 11.73 | 4 | 84.87 | 111.01 |
| 1 | .376 | .497 | 11.79 | 4 | 88.75 | 109.94 |
| Mean | .376 | .518 | 11.598 | ..... | 75.38 | ..... |

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### HOLYOKE TESTS OF HERCULES TURBINES.

The Hercules turbine has been developed by elaborate experiments from the original design of John B. McCormick. The runners are very carefully finished, and the guide and bucket openings are made to conform with standard gauges, resulting in great uniformity of the output.

Tests of five sizes of Hercules turbines from recent patterns have been furnished by the Worcester (Mass.) shops of the Holyoke Machine Company. The mean head, speed, discharge, power, and efficiency for each group of experiments made with a given size of wheel and proportional gate opening have been computed and are given in the tables.

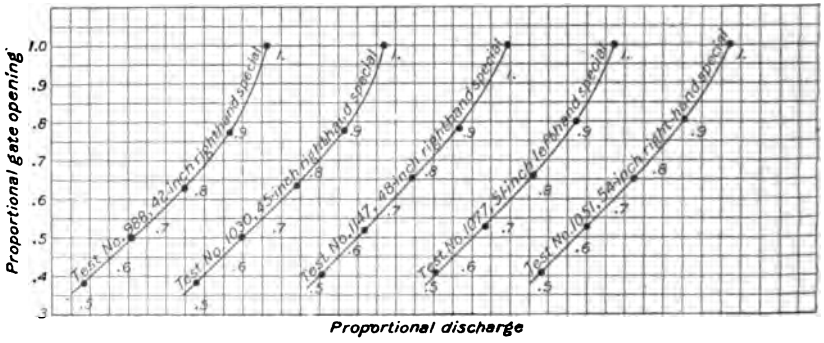


FIG. 24.—Proportional discharge coefficients for Hercules special turbines.

*Holyoke tests of Hercules turbines.*[a]

42-INCH RIGHT-HAND SPECIAL WHEEL.

[Test No. 988, February 18–19, 1897.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharge (discharge at full gate with highest efficiency = 1). | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. | Horsepower developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 8 | 1.000 | 1.011 | 15.73 | 4 | 113.25 | 141.39 | 201.37 | 79.84 |
| 7 | 1.000 | 1.006 | 15.73 | 4 | 116.75 | 140.77 | 201.85 | 80.38 |
| 6 | 1.000 | 1.002 | 15.73 | 4 | 119.75 | 140.25 | 201.14 | 80.39 |
| 5 | 1.000 | .998 | 15.76 | 5 | 122.40 | 139.72 | 199.57 | 79.92 |
| 4 | 1.000 | .993 | 15.80 | 4 | 125.87 | 139.20 | 199.03 | 79.80 |
| 3 | 1.000 | .983 | 15.83 | 4 | 130.87 | 138.01 | 197.28 | 79.62 |
| 2 | 1.000 | .975 | 15.82 | 4 | 136.00 | 136.85 | 192.46 | 78.39 |
| 1 | 1.000 | .962 | 15.78 | 4 | 142.25 | 134.78 | 183.80 | 76.20 |
| 43 | 1.000 | .714 | 16.54 | 4 | 200.50 | 102.50 | ..... | ..... |
| Mean | ..... | .960 | 15.857 | ..... | 134.182 | 134.83 | 197.062 | 79.317 |
| 17 | .778 | .894 | 16.18 | 4 | 104.37 | 126.89 | 186.23 | 79.98 |
| 16 | .778 | .887 | 16.20 | 4 | 108.75 | 125.98 | 187.31 | 80.94 |
| 15 | .778 | .881 | 16.25 | 4 | 113.00 | 125.23 | 187.72 | 81.34 |
| 14 | .778 | .875 | 16.30 | 4 | 117.50 | 124.61 | 187.96 | 81.60 |
| 13 | .778 | .867 | 16.35 | 4 | 121.37 | 123.72 | 186.69 | 81.38 |
| 12 | .778 | .860 | 16.28 | 4 | 124.75 | 122.45 | 183.45 | 81.14 |
| 11 | .778 | .854 | 16.30 | 4 | 128.62 | 121.60 | 180.43 | 80.27 |
| 10 | .778 | .846 | 16.34 | 4 | 132.62 | 120.60 | 177.07 | 79.23 |
| 9 | .778 | .836 | 16.34 | 4 | 139.25 | 119.23 | 171.35 | 77.56 |
| Mean | ..... | .866 | 16.282 | ..... | 121.136 | 123.36 | 183.13 | 80.38 |

[a] Made by ... ine Company, Holyoke, Mass.

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*Holyoke tests of Hercules turbines*—Continued.

42-INCH RIGHT-HAND SPECIAL WHEEL—Continued.

| Number of experiment. | Gate opening (proportion part). | Proportional discharge (discharge at full gate with highest efficiency = 1). | Mean head, in feet. | Duration of test, in minutes. | Revolutions per minute. | Discharge, in second-feet. | Horse-power developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 25 | 0.633 | 0.765 | 16.48 | 4 | 102.50 | 109.61 | 158.29 | 77.27 |
| 24 | .633 | .760 | 16.51 | 5 | 108.00 | 109.01 | 161.47 | 79.11 |
| 23 | .633 | .756 | 16.54 | 4 | 112.00 | 108.40 | 161.94 | 79.64 |
| 22 | .633 | .750 | 16.56 | 4 | 116.00 | 107.69 | 162.01 | 80.11 |
| 21 | .633 | .747 | 16.52 | 4 | 118.50 | 107.08 | 159.67 | 79.59 |
| 20 | .633 | .742 | 16.53 | 4 | 122.00 | 106.38 | 158.38 | 79.42 |
| 19 | .633 | .733 | 16.57 | 4 | 127.00 | 105.33 | 156.28 | 78.95 |
| 18 | .633 | .723 | 16.58 | 4 | 133.50 | 103.91 | 151.96 | 77.77 |
| Mean | | .747 | 16.536 | | 117.437 | 107.176 | 158.75 | 78.98 |
| 34 | .501 | .627 | 16.86 | 5 | 103.00 | 90.81 | 127.38 | 73.36 |
| 33 | .501 | .625 | 16.80 | 4 | 105.62 | 90.36 | 127.37 | 73.98 |
| 32 | .501 | .620 | 16.83 | 4 | 110.50 | 89.80 | 128.50 | 74.97 |
| 31 | .501 | .616 | 16.87 | 4 | 114.50 | 89.23 | 128.22 | 75.10 |
| 30 | .501 | .610 | 16.84 | 4 | 118.25 | 88.34 | 126.60 | 75.04 |
| 29 | .501 | .605 | 16.79 | 4 | 121.50 | 87.44 | 124.09 | 74.53 |
| 28 | .501 | .599 | 16.82 | 4 | 124.87 | 86.65 | 121.39 | 73.44 |
| 27 | .501 | .591 | 16.82 | 4 | 129.37 | 85.57 | 117.80 | 72.17 |
| 26 | .501 | .583 | 16.89 | 4 | 135.50 | 84.47 | 112.55 | 69.56 |
| Mean | | .6084 | 16.835 | | 118.12 | 88.074 | 123.76 | 73.57 |
| 42 | .382 | .502 | 17.05 | 4 | 98.75 | 73.12 | 95.39 | 67.47 |
| 41 | .382 | .500 | 17.08 | 4 | 104.00 | 72.91 | 96.62 | 68.42 |
| 40 | .382 | .496 | 17.09 | 4 | 108.25 | 72.27 | 96.58 | 68.95 |
| 39 | .382 | .491 | 17.09 | 4 | 111.50 | 71.65 | 95.36 | 68.67 |
| 38 | .382 | .487 | 17.12 | 4 | 114.87 | 71.03 | 94.00 | 68.16 |
| 37 | .382 | .482 | 17.13 | 4 | 119.75 | 70.43 | 92.10 | 67.31 |
| 36 | .382 | .475 | 17.18 | 4 | 126.25 | 69.39 | 87.78 | 64.92 |
| 35 | .382 | .467 | 17.20 | 4 | 133.12 | 68.26 | 81.91 | 61.51 |
| Mean | | .4875 | 17.12 | | 114.56 | 71.13 | 92.217 | 66.926 |

45-INCH RIGHT-HAND SPECIAL WHEEL

[Test No. 1030, July 19, 1897.]

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10 | 1.000 | 1.024 | 15.81 | 5 | 96.20 | 163.23 | 236.04 | 80.79 |
| 9 | 1.000 | 1.016 | 15.79 | 4 | 99.75 | 161.85 | 235.94 | 81.55 |
| 8 | 1.000 | 1.012 | 15.78 | 4 | 103.67 | 161.15 | 236.05 | 82.00 |
| 7 | 1.000 | 1.007 | 15.78 | 5 | 108.00 | 160.35 | 236.36 | 82.51 |
| 6 | 1.000 | 1.001 | 15.75 | 5 | 111.20 | 159.25 | 234.30 | 82.52 |
| 5 | 1.000 | .997 | 15.74 | 4 | 115.00 | 158.54 | 232.92 | 82.45 |
| 4 | 1.000 | .990 | 15.78 | 5 | 119.60 | 157.60 | 231.67 | 82.29 |
| 3 | 1.000 | .982 | 15.84 | 5 | 124.60 | 156.67 | 228.66 | 81.39 |
| 2 | 1.000 | .969 | 15.84 | 4 | 130.25 | 154.48 | 221.32 | 79.89 |
| 1 | 1.000 | .952 | 15.98 | 4 | 135.25 | 152.45 | 211.43 | 76.66 |
| 44 | 1.000 | .712 | 16.80 | 5 | 188.60 | 116.90 | | |
| Mean | | .969 | 15.899 | | 121.10 | 154.77 | 230.469 | 81.205 |

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*Holyoke tests of Hercules turbines*—Continued.

45-INCH RIGHT-HAND SPECIAL WHEEL—Continued.

| Number of experiment. | Gate opening (proportion part). | Proportional discharge (discharge at full gate with highest efficiency = 1). | Mean head, in feet. | Duration of test, in minutes. | Revolutions per minute. | Discharge, in second-feet. | Horse-power developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 18 | 0.779 | 0.894 | 16.24 | 4 | 97.25 | 144.31 | 216.80 | 81.72 |
| 17 | .779 | .887 | 16.26 | 4 | 101.25 | 143.35 | 218.15 | 82.67 |
| 16 | .779 | .880 | 16.30 | 4 | 105.62 | 142.43 | 218.23 | 83.03 |
| 15 | .779 | .873 | 16.34 | 4 | 110.50 | 141.41 | 218.55 | 83.55 |
| 14 | .779 | .866 | 16.36 | 5 | 114.00 | 140.38 | 215.40 | 82.85 |
| 13 | .779 | .856 | 16.39 | 4 | 117.62 | 138.81 | 211.85 | 82.25 |
| 12 | .779 | .846 | 16.38 | 5 | 122.00 | 137.25 | 207.30 | 81.45 |
| 11 | .779 | .834 | 16.40 | 4 | 128.25 | 135.42 | 200.49 | 79.74 |
| Mean | | .867 | 16.33 | | 112.06 | 140.42 | 213.34 | 82.157 |
| 26 | .636 | .770 | 16.63 | 4 | 96.62 | 125.86 | 187.82 | 79.26 |
| 25 | .636 | .766 | 16.66 | 4 | 100.75 | 125.23 | 189.00 | 80.02 |
| 24 | .636 | .760 | 16.68 | 5 | 105.00 | 124.36 | 189.12 | 80.54 |
| 23 | .636 | .752 | 16.71 | 4 | 109.25 | 123.21 | 188.61 | 80.92 |
| 22 | .636 | .745 | 16.74 | 4 | 112.75 | 122.21 | 186.22 | 80.41 |
| 21 | .636 | .738 | 16.75 | 5 | 117.40 | 120.98 | 183.53 | 80.00 |
| 20 | .636 | .728 | 16.72 | 4 | 122.25 | 119.23 | 178.64 | 79.16 |
| 19 | .636 | .716 | 16.72 | 5 | 127.00 | 117.39 | 172.64 | 77.70 |
| Mean | | .7468 | 16.701 | | 111.37 | 122.308 | 184.435 | 79.75 |
| 34 | .502 | .632 | 16.89 | 4 | 95.87 | 104.14 | 149.22 | 74.94 |
| 33 | .502 | .627 | 16.92 | 5 | 100.60 | 103.31 | 150.43 | 76.02 |
| 32 | .502 | .620 | 16.97 | 4 | 105.12 | 102.36 | 150.75 | 76.66 |
| 31 | .502 | .616 | 16.98 | 4 | 108.75 | 101.66 | 149.31 | 76.40 |
| 30 | .502 | .611 | 17.01 | 4 | 112.00 | 100.97 | 147.68 | 75.95 |
| 29 | .502 | .601 | 17.07 | 4 | 116.50 | 99.59 | 144.11 | 74.86 |
| 28 | .502 | .591 | 17.14 | 5 | 122.60 | 98.07 | 139.16 | 73.13 |
| 27 | .502 | .583 | 17.15 | 4 | 126.75 | 96.70 | 133.53 | 71.12 |
| 43 | .502 | .484 | 17.49 | 4 | 179.00 | 81.20 | | |
| Mean | | .596 | 17.067 | | 118.576 | 98.66 | 145.52 | 74.88 |
| 42 | .386 | .500 | 17.34 | 4 | 96.75 | 83.47 | 113.10 | 69.03 |
| 41 | .386 | .494 | 17.37 | 4 | 101.25 | 82.49 | 112.86 | 69.58 |
| 40 | .386 | .489 | 17.38 | 4 | 105.75 | 81.72 | 111.41 | 69.29 |
| 39 | .386 | .484 | 17.37 | 4 | 109.12 | 80.88 | 109.02 | 68.55 |
| 38 | .386 | .478 | 17.40 | 4 | 114.25 | 79.91 | 106.38 | 67.59 |
| 37 | .386 | .472 | 17.39 | 4 | 118.25 | 78.83 | 102.07 | 65.77 |
| 36 | .386 | .465 | 17.39 | 5 | 123.20 | 77.65 | 96.30 | 62.99 |
| 35 | .386 | .456 | 17.40 | 5 | 129.80 | 76.15 | 88.22 | 58.81 |
| Mean | | .4797 | 17.38 | | 112.296 | 80.137 | 104.92 | 66.45 |

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*Holyoke tests of Hercules turbines*—Continued.

48-INCH RIGHT-HAND SPECIAL WHEEL.

[Test No. 1147, October 10–11, 1898.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharge (discharge at full gate with highest efficiency = 1). | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. | Horsepower developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| ..... | 1.000 | 1.026 | 15.47 | 4 | 89.50 | 182.27 | 255.49 | 79.95 |
| ..... | 1.000 | 1.018 | 15.46 | 4 | 93.25 | 180.83 | 256.69 | 81.02 |
| ..... | 1.000 | 1.011 | 15.52 | 4 | 97.00 | 179.85 | 257.12 | 81.28 |
| ..... | 1.000 | 1.005 | 15.51 | 4 | 100.50 | 178.69 | 256.15 | 81.55 |
| ..... | 1.000 | .998 | 15.53 | 4 | 104.25 | 177.57 | 255.08 | 81.62 |
| ..... | 1.000 | .986 | 15.62 | 4 | 109.62 | 175.98 | 253.32 | 81.32 |
| ..... | 1.000 | .978 | 15.56 | 4 | 113.75 | 174.16 | 247.40 | 80.56 |
| ..... | 1.000 | .969 | 15.57 | 5 | 119.00 | 172.76 | 242.64 | 79.60 |
| ..... | 1.000 | .957 | 15.68 | 4 | 124.25 | 171.05 | 236.46 | 77.79 |
| Mean..... | ..... | .994 | 15.55 | ..... | 105.68 | 177.02 | 251.15 | 80.52 |
| ..... | .784 | .888 | 16.12 | 5 | 90.80 | 161.09 | 235.13 | 79.90 |
| ..... | .784 | .885 | 16.08 | 4 | 95.50 | 160.27 | 238.86 | 81.78 |
| ..... | .784 | .878 | 16.24 | 4 | 101.00 | 159.87 | 242.32 | 82.36 |
| ..... | .784 | .872 | 16.30 | 4 | 104.50 | 158.90 | 241.49 | 82.27 |
| ..... | .784 | .863 | 16.38 | 5 | 108.30 | 157.79 | 239.23 | 81.67 |
| ..... | .784 | .853 | 16.40 | 4 | 112.75 | 156.05 | 233.73 | 80.59 |
| ..... | .784 | .841 | 16.34 | 4 | 117.37 | 153.57 | 227.35 | 79.95 |
| ..... | .784 | .832 | 16.34 | 4 | 124.50 | 151.83 | 220.01 | 78.25 |
| Mean..... | ..... | .864 | 16.275 | ..... | 106.84 | 157.42 | 234.76 | 80.85 |
| ..... | .651 | .768 | 16.32 | 4 | 93.87 | 140.07 | 204.16 | 78.81 |
| ..... | .651 | .763 | 16.35 | 4 | 100.00 | 139.27 | 207.30 | 80.33 |
| ..... | .651 | .756 | 16.35 | 4 | 104.62 | 137.97 | 206.21 | 80.66 |
| ..... | .651 | .747 | 16.37 | 4 | 109.25 | 136.54 | 204.20 | 80.61 |
| ..... | .651 | .740 | 16.41 | 4 | 113.00 | 135.37 | 199.69 | 79.32 |
| ..... | .651 | .730 | 16.42 | 4 | 116.62 | 133.57 | 194.20 | 78.13 |
| ..... | .651 | .717 | 16.45 | 4 | 121.50 | 131.27 | 185.81 | 75.93 |
| Mean..... | ..... | .746 | 16.38 | ..... | 108.41 | 136.29 | 200.22 | 79.11 |
| ..... | .521 | .635 | 16.74 | 4 | 89.75 | 117.34 | 161.65 | 72.62 |
| ..... | .521 | .632 | 16.77 | 4 | 97.25 | 116.97 | 167.23 | 75.23 |
| ..... | .521 | .626 | 16.82 | 4 | 102.25 | 115.97 | 167.49 | 75.76 |
| ..... | .521 | .618 | 16.84 | 4 | 106.25 | 114.53 | 164.65 | 75.33 |
| ..... | .521 | .610 | 16.85 | 4 | 110.25 | 113.07 | 161.11 | 74.62 |
| ..... | .521 | .602 | 16.86 | 4 | 114.25 | 111.59 | 155.31 | 72.84 |
| ..... | .521 | .595 | 16.87 | 4 | 118.20 | 110.28 | 148.62 | 70.49 |
| Mean..... | ..... | .617 | 16.82 | ..... | 105.45 | 114.25 | 160.86 | 73.84 |
| ..... | .402 | .520 | 17.07 | 4 | 90.00 | 96.98 | 128.46 | 68.47 |
| ..... | .402 | .516 | 17.08 | 4 | 95.75 | 96.31 | 130.16 | 69.82 |
| ..... | .402 | .511 | 17.07 | 4 | 100.00 | 95.29 | 129.14 | 70.05 |
| ..... | .402 | .505 | 17.10 | 4 | 103.62 | 94.38 | 126.77 | 69.31 |
| ..... | .402 | .502 | 17.11 | 4 | 106.62 | 93.70 | 123.19 | 67.80 |
| ..... | .402 | .496 | 17.14 | 4 | 110.62 | 92.66 | 120.30 | 66.84 |
| ..... | .402 | .489 | 17.15 | 4 | 115.62 | 91.42 | 113.95 | 64.13 |
| ..... | .402 | .482 | 17.18 | 4 | 120.50 | 90.17 | 106.47 | 60.65 |
| Mean..... | ..... | .503 | 17.11 | ..... | 105.34 | 93.86 | 122.305 | 67.13 |

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*Holyoke tests of Hercules turbines*—Continued.

51-INCH LEFT-HAND SPECIAL WHEEL.

[Test No. 1077, February 25, 1898.]

| Number of experiment. | Gate opening (proportional part). | Proportional discharge (discharge at full gate with highest efficiency = 1). | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. | Horse-power developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 46 | 1.000 | 1.022 | 13.86 | 4 | Still. | 204.26 | ..... | ..... |
| 45 | 1.000 | 1.016 | 13.96 | 4 | 83.00 | 203.83 | 267.40 | 82.86 |
| 44 | 1.000 | 1.011 | 13.94 | 4 | 85.50 | 202.64 | 267.32 | 83.44 |
| 43 | 1.000 | 1.004 | 14.00 | 4 | 88.50 | 201.58 | 268.27 | 83.82 |
| 42 | 1.000 | 1.000 | 14.01 | 4 | 91.25 | 200.98 | 267.93 | 83.90 |
| 41 | 1.000 | .992 | 14.05 | 5 | 93.80 | 199.65 | 266.49 | 83.77 |
| 40 | 1.000 | .987 | 14.04 | 5 | 95.60 | 198.45 | 262.51 | 83.08 |
| 39 | 1.000 | .978 | 14.11 | 4 | 99.00 | 197.26 | 261.75 | 82.92 |
| 38 | 1.000 | .975 | 14.14 | 6 | 102.08 | 196.83 | 259.49 | 82.21 |
| 37 | 1.000 | .967 | 14.20 | 4 | 106.12 | 195.65 | 257.49 | 81.72 |
| 36 | 1.000 | .959 | 14.28 | 5 | 109.30 | 194.46 | 252.58 | 80.20 |
| 35 | 1.000 | .949 | 14.35 | 3 | 113.33 | 192.85 | 246.49 | 78.54 |
| 47 | 1.000 | .731 | 15.62 | 4 | 164.50 | 155.15 | ..... | ..... |
| Mean | ..... | 9.685 | 14.196 | ..... | 102.665 | 195.66 | 261.61 | 82.405 |
| 34 | .800 | .902 | 14.50 | 4 | 83.37 | 184.33 | 250.46 | 82.63 |
| 33 | .800 | .894 | 14.54 | 4 | 87.37 | 183.04 | 252.38 | 83.62 |
| 32 | .800 | .886 | 14.61 | 4 | 90.62 | 181.74 | 251.30 | 83.45 |
| 31 | .800 | .878 | 14.64 | 4 | 93.87 | 180.30 | 249.46 | 83.33 |
| 30 | .800 | .871 | 14.65 | 4 | 96.87 | 178.90 | 246.24 | 82.84 |
| 29 | .800 | .864 | 14.63 | 4 | 99.87 | 177.45 | 242.33 | 82.31 |
| 28 | .800 | .857 | 14.64 | 4 | 103.25 | 176.01 | 238.60 | 81.65 |
| 27 | .800 | .851 | 14.68 | 4 | 107.50 | 174.90 | 233.81 | 80.30 |
| 26 | .800 | .841 | 14.75 | 3 | 111.33 | 173.35 | 227.00 | 78.28 |
| Mean | ..... | .872 | 14.626 | ..... | 97.116 | 178.89 | 243.508 | 82.40 |
| 25 | .660 | .789 | 14.97 | 4 | 83.00 | 163.76 | 221.14 | 79.54 |
| 24 | .660 | .781 | 15.02 | 4 | 87.25 | 162.37 | 223.57 | 80.83 |
| 23 | .660 | .775 | 15.05 | 5 | 90.70 | 161.27 | 223.16 | 81.07 |
| 22 | .660 | .767 | 15.12 | 4 | 94.50 | 160.17 | 222.87 | 81.15 |
| 21 | .660 | .761 | 15.16 | 5 | 98.10 | 159.08 | 221.36 | 80.96 |
| 20 | .660 | .754 | 15.17 | 5 | 101.40 | 157.72 | 218.47 | 80.58 |
| 19 | .660 | .748 | 15.19 | 4 | 105.00 | 156.48 | 215.52 | 79.96 |
| 18 | .660 | .741 | 15.22 | 4 | 109.12 | 155.26 | 211.37 | 78.87 |
| 17 | .660 | .732 | 15.26 | 4 | 112.75 | 153.50 | 203.08 | 76.44 |
| Mean | ..... | .761 | 15.128 | ..... | 97.98 | 158.84 | 217.837 | 79.93 |
| 16 | .530 | .658 | 15.61 | 4 | 79.75 | 139.58 | 183.21 | 74.15 |
| 15 | .530 | .654 | 15.64 | 4 | 84.50 | 138.80 | 186.08 | 75.58 |
| 14 | .530 | .648 | 15.67 | 5 | 88.90 | 137.63 | 187.31 | 76.58 |
| 13 | .530 | .644 | 15.69 | 5 | 92.80 | 136.85 | 186.70 | 76.67 |
| 12 | .530 | .637 | 15.72 | 5 | 96.80 | 135.55 | 184.88 | 76.50 |
| 11 | .530 | .629 | 15.75 | 4 | 101.00 | 134.01 | 181.23 | 75.71 |
| 10 | .530 | .622 | 15.79 | 4 | 105.50 | 132.59 | 177.11 | 74.59 |
| 9 | .530 | .614 | 15.84 | 4 | 109.00 | 131.18 | 170.39 | 72.31 |
| Mean | ..... | .638 | 15.713 | ..... | 94.53 | 135.77 | 182.113 | 75.26 |

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*Holyoke tests of Hercules turbines*—Continued.

51-INCH LEFT-HAND SPECIAL WHEEL—Continued.

| Number of experiment. | Gate opening (proportional part). | Proportional discharge (discharge at full gate with highest efficiency=1). | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. | Horsepower developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 8 | 0.410 | 0.525 | 16.22 | 5 | 79.20 | 113.53 | 142.65 | 68.31 |
| 7 | .410 | .521 | 16.24 | 4 | 83.50 | 112.66 | 143.58 | 69.20 |
| 6 | .410 | .516 | 16.24 | 4 | 87.50 | 111.66 | 143.33 | 69.69 |
| 5 | .410 | .510 | 16.29 | 4 | 92.50 | 110.45 | 142.71 | 69.94 |
| 4 | .410 | .502 | 16.36 | 4 | 97.75 | 109.00 | 139.52 | 68.99 |
| 3 | .410 | .494 | 16.38 | 5 | 103.60 | 107.33 | 133.79 | 67.10 |
| 2 | .410 | .486 | 16.41 | 4 | 109.00 | 105.68 | 125.94 | 64.04 |
| 1 | .410 | .478 | 16.46 | 4 | 114.75 | 104.03 | 116.99 | 60.24 |
| Mean | ..... | .504 | 16.325 | ..... | 95.975 | 109.29 | 136.063 | 67.188 |
| 68 | .091 | .148 | 17.68 | 4 | 102.75 | 33.36 | ..... | ..... |

54-INCH RIGHT-HAND SPECIAL WHEEL.

[Test No. 1051, November 12, 1897.]

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 42 | 1.000 | 1.004 | 13.98 | 5 | 80.40 | 230.06 | 305.38 | 83.72 |
| 41 | 1.000 | .997 | 14.07 | 4 | 84.12 | 228.98 | 306.94 | 84.00 |
| 40 | 1.000 | .989 | 14.13 | 4 | 87.00 | 227.80 | 305.62 | 83.71 |
| 39 | 1.000 | .981 | 14.22 | 4 | 90.50 | 226.71 | 305.62 | 83.58 |
| 38 | 1.000 | .974 | 14.26 | 4 | 94.00 | 225.30 | 303.39 | 83.26 |
| 37 | 1.000 | .964 | 14.29 | 4 | 98.00 | 223.16 | 299.65 | 82.83 |
| 36 | 1.000 | .956 | 14.34 | 4 | 101.50 | 221.65 | 293.11 | 81.31 |
| 35 | 1.000 | .944 | 14.38 | 4 | 104.87 | 219.38 | 285.03 | 79.66 |
| Mean | ..... | .976 | 14.21 | ..... | 92.548 | 225.38 | 300.59 | 82.76 |
| 34 | .800 | .881 | 14.69 | 4 | 80.00 | 206.93 | 287.01 | 83.25 |
| 33 | .800 | .875 | 14.73 | 5 | 83.20 | 205.72 | 287.19 | 83.56 |
| 32 | .800 | .868 | 14.80 | 5 | 86.60 | 204.66 | 287.16 | 83.59 |
| 31 | .800 | .859 | 14.87 | 4 | 90.25 | 202.98 | 286.38 | 83.65 |
| 30 | .800 | .852 | 14.94 | 4 | 93.75 | 201.77 | 284.75 | 83.28 |
| 29 | .800 | .844 | 15.01 | 4 | 97.12 | 200.41 | 281.78 | 82.59 |
| 28 | .800 | .836 | 15.07 | 4 | 101.00 | 198.92 | 277.94 | 81.75 |
| 27 | .800 | .829 | 15.09 | 4 | 104.87 | 197.26 | 270.78 | 80.20 |
| 26 | .800 | .820 | 15.15 | 5 | 108.40 | 195.46 | 261.48 | 77.85 |
| Mean | ..... | .852 | 14.82 | ..... | 93.91 | 201.567 | 280.496 | 82.19 |
| 25 | .650 | .749 | 15.38 | 5 | 77.00 | 179.88 | 246.95 | 78.70 |
| 24 | .650 | .745 | 15.40 | 5 | 81.00 | 179.02 | 250.42 | 80.09 |
| 23 | .650 | .739 | 15.45 | 5 | 84.60 | 177.87 | 251.78 | 80.78 |
| 22 | .650 | .734 | 15.48 | 5 | 88.60 | 176.85 | 252.85 | 81.43 |
| 21 | .650 | .728 | 15.49 | 5 | 92.80 | 175.59 | 252.22 | 81.76 |
| 20 | .650 | .722 | 15.47 | 5 | 95.80 | 173.91 | 248.01 | 81.28 |
| 19 | .650 | .714 | 15.50 | 4 | 99.25 | 172.09 | 242.10 | 80.02 |
| 18 | .650 | .705 | 15.53 | 5 | 102.40 | 170.10 | 234.48 | 78.26 |
| 17 | .650 | .696 | 15.57 | 4 | 105.75 | 168.14 | 226.34 | 76.23 |
| Mean | ..... | .726 | 15.47 | ..... | 91.91 | 174.83 | 245.02 | 79.84 |



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*Holyoke tests of Hercules turbines*—Continued.

54-INCH RIGHT-HAND SPECIAL WHEEL—Continued.

| Number of experiment. | Gate opening (proportional part). | Proportional discharge (discharge at full gate with highest efficiency=1). | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. | Horsepower developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 16 | 0.527 | 0.622 | 15.97 | 4 | 74.50 | 152.27 | 202.49 | 73.42 |
| 15 | .527 | .618 | 16.01 | 4 | 78.87 | 151.47 | 205.79 | 74.82 |
| 14 | .527 | .612 | 16.03 | 4 | 83.12 | 150.12 | 207.28 | 75.94 |
| 13 | .527 | .606 | 16.09 | 4 | 87.25 | 148.80 | 207.50 | 76.41 |
| 12 | .527 | .597 | 16.12 | 4 | 91.62 | 146.94 | 205.44 | 76.47 |
| 11 | .527 | .591 | 16.15 | 4 | 95.37 | 145.60 | 200.89 | 75.32 |
| 10 | .527 | .584 | 16.22 | 4 | 99.25 | 143.98 | 195.57 | 73.94 |
| 9 | .527 | .578 | 16.23 | 4 | 103.00 | 142.55 | 188.96 | 72.01 |
| Mean | | .601 | 16.10 | | 89.12 | 147.72 | 201.74 | 74.77 |
| 8 | .410 | .499 | 16.58 | 4 | 77.00 | 124.59 | 163.24 | 69.67 |
| 7 | .410 | .494 | 16.63 | 4 | 81.62 | 123.44 | 163.61 | 70.27 |
| 6 | .410 | .489 | 16.64 | 4 | 85.50 | 122.20 | 162.67 | 70.55 |
| 5 | .410 | .483 | 16.68 | 4 | 90.50 | 120.82 | 159.88 | 69.96 |
| 4 | .410 | .478 | 16.66 | 4 | 94.75 | 119.58 | 154.51 | 68.38 |
| 3 | .410 | .472 | 16.68 | 5 | 99.10 | 118.20 | 148.14 | 66.25 |
| 2 | .410 | .467 | 16.73 | 4 | 103.75 | 117.00 | 140.99 | 63.51 |
| 1 | .410 | .460 | 16.79 | 5 | 109.30 | 115.53 | 129.97 | 59.07 |
| Mean | | .480 | 16.67 | | 92.69 | 120.17 | 152.88 | 67.20 |

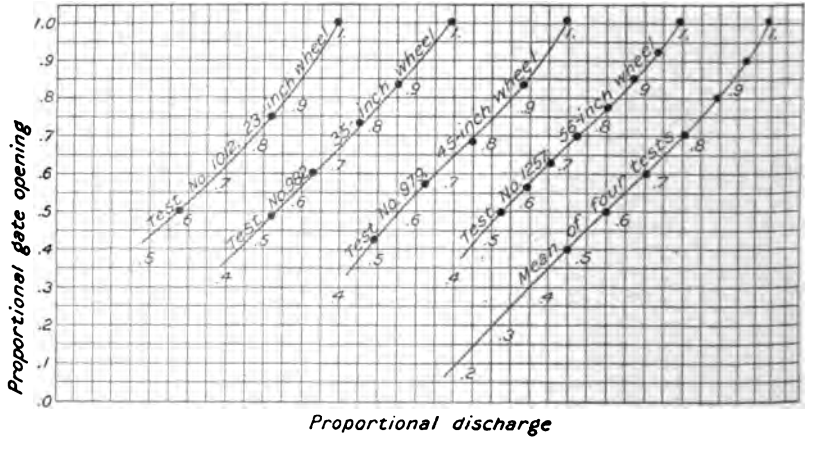


FIG. 25.—Proportional discharge coefficients for Leffel-Samson turbines.

HOLYOKE TESTS OF SAMSON TURBINES.

The Samson turbine is constructed by James Leffel & Co., Springfield, Ohio. It has been developed along lines similar to the earlier Leffel wheels, but with greatly increased depth and capacity. The runner resembles that of the McCormick turbines, except that a division plate provides for a narrow ring of inward discharge buckets near the top. It is oper-

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ated with pivoted gates, differing in this respect from the Victor, Hercules, McCormick, and most other large-capacity turbines, which are provided with cylinder gates.

Complete Holyoke tests of three sizes of Samson wheels have been furnished by the builders. The means of the factors for each group of experiments in the tests are given in the tables, together with the original data of the tests.

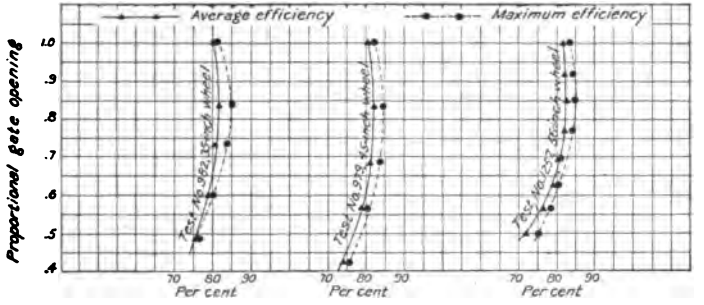


FIG. 26.—Efficiency curves for Leffel-Samson turbines.

*Holyoke tests of Samson turbines.*

35-INCH RIGHT-HAND WHEEL.

[Test No. 982, February 1, 1897.]

| Number of tests. | Gate opening (proportional part). | Proportional discharge. (Discharge of full gate at highest efficiency=1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. | Horse-power developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 7 | 1.000 | 0.989 | 15.23 | 4 | 171.00 | 100.85 | 138.90 | 79.74 |
| 3 | 1.000 | .994 | 15.20 | 5 | 179.60 | 101.31 | 140.36 | 80.37 |
| 4 | 1.000 | .996 | 15.18 | 4 | 186.50 | 101.43 | 141.16 | 80.84 |
| 2 | 1.000 | .998 | 15.29 | 4 | 194.25 | 102.02 | 143.44 | 81.08 |
| 5 | 1.000 | 1.002 | 15.25 | 4 | 201.75 | 102.25 | 142.77 | 80.74 |
| 1 | 1.000 | .999 | 15.34 | 4 | 209.00 | 102.25 | 141.47 | 79.53 |
| 6 | 1.000 | .997 | 15.29 | 3 | 214.67 | 101.90 | 138.71 | 78.50 |
| Mean | | .996 | 15.25 | | 193.82 | 101.72 | 140.97 | 80.11 |
| 16 | .834 | .865 | 16.62 | 4 | 171.25 | 92.15 | 144.37 | 83.12 |
| 15 | .834 | .869 | 16.59 | 4 | 181.25 | 92.49 | 147.23 | 84.60 |
| 14 | .834 | .866 | 16.56 | 4 | 187.75 | 92.15 | 146.73 | 84.78 |
| 13 | .834 | .864 | 16.48 | 4 | 195.00 | 91.69 | 144.00 | 84.03 |
| 12 | .834 | .858 | 16.24 | 3 | 197.33 | 90.36 | 137.22 | 82.45 |
| 11 | .834 | .855 | 15.79 | 4 | 196.50 | 88.79 | 129.38 | 81.37 |
| 10 | .834 | .845 | 15.74 | 4 | 200.50 | 87.65 | 124.61 | 79.65 |
| 9 | .834 | .838 | 15.69 | 4 | 203.75 | 86.77 | 120.37 | 77.96 |
| 8 | .834 | .826 | 15.63 | 4 | 206.25 | 85.36 | 116.77 | 77.17 |
| Mean | | .854 | 16.15 | | 193.28 | 89.72 | 134.52 | 81.68 |

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*Holyoke tests of Samson turbines*—Continued.

35-INCH RIGHT-HAND WHEEL—Continued.

| Number of tests. | Gate opening (proportional part). | Proportional discharge. (Discharge of full gate at highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. | Horse-power developed. | Percentage of efficiency |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 25 | 0.733 | 0.770 | 17.32 | 4 | 163.25 | 83.70 | 133.61 | 81.27 |
| 24 | .733 | .771 | 17.34 | 4 | 170.75 | 83.95 | 136.60 | 82.74 |
| 23 | .733 | .772 | 17.33 | 4 | 178.50 | 83.95 | 138.40 | 83.88 |
| 22 | .733 | .769 | 17.32 | 4 | 183.75 | 83.62 | 136.82 | 83.30 |
| 21 | .733 | .762 | 17.31 | 4 | 187.00 | 82.84 | 133.49 | 82.08 |
| 20 | .733 | .753 | 17.32 | 4 | 192.25 | 81.87 | 130.13 | 80.92 |
| 19 | .733 | .735 | 17.38 | 4 | 200.75 | 80.40 | 126.00 | 79.87 |
| 18 | .733 | .729 | 17.38 | 4 | 214.00 | 79.38 | 121.15 | 77.43 |
| 17 | .733 | .717 | 17.36 | 4 | 227.75 | 78.12 | 112.12 | 72.90 |
| Mean | | .753 | 17.34 | | 190.88 | 81.94 | 129.81 | 80.48 |
| 32 | .601 | .644 | 17.53 | 4 | 160.00 | 70.45 | 111.26 | 79.44 |
| 31 | .601 | .642 | 17.55 | 4 | 167.00 | 70.34 | 112.01 | 80.01 |
| 30 | .601 | .636 | 17.54 | 4 | 170.50 | 69.63 | 110.17 | 79.54 |
| 29 | .601 | .629 | 17.54 | 5 | 176.40 | 68.82 | 109.64 | 80.09 |
| 28 | .601 | .627 | 17.55 | 4 | 182.75 | 68.60 | 109.08 | 79.89 |
| 27 | .601 | .623 | 17.56 | 4 | 188.25 | 68.28 | 107.73 | 79.23 |
| 26 | .601 | .616 | 17.58 | 4 | 198.75 | 67.46 | 103.96 | 77.29 |
| Mean | | .631 | 17.55 | | 177 06 | 69.08 | 109.12 | 79.35 |
| 37 | .488 | .527 | 17.66 | 4 | 155.75 | 57.88 | 87.22 | 75.24 |
| 36 | .488 | .526 | 17.66 | 4 | 162.25 | 57.79 | 87.86 | 75.91 |
| 35 | .488 | .525 | 17.68 | 4 | 168.50 | 57.69 | 88.14 | 76.19 |
| 34 | .488 | .523 | 17.69 | 4 | 174.00 | 57.51 | 87.80 | 76.10 |
| 33 | .488 | .518 | 17.72 | 4 | 180.75 | 57.03 | 86.76 | 75.70 |
| 38 | .488 | .513 | 17.67 | 4 | 194.00 | 56.38 | 83.57 | 73.96 |
| Mean | | .522 | 17.68 | | 172.54 | 57.36 | 86.89 | 75.51 |

45-INCH RIGHT-HAND WHEEL.

[Test No. 979, January 25-26, 1897.]

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8 | 1.000 | 0.992 | 14.94 | 5 | 127.60 | 171.24 | 233.49 | 80.48 |
| 7 | 1.000 | 1.000 | 14.88 | 5 | 133.40 | 172.12 | 236.84 | 81.54 |
| 6 | 1.000 | .998 | 14.92 | 4 | 138 12 | 172.12 | 238.65 | 81.94 |
| 5 | 1.000 | .999 | 15.00 | 4 | 144.00 | 172.69 | 240.97 | 82.03 |
| 4 | 1.000 | 1.001 | 15.02 | 4 | 148.75 | 173.23 | 240.82 | 81.61 |
| 3 | 1.000 | 1.002 | 15.03 | 3 | 153.33 | 173.38 | 239.89 | 81.18 |
| 2 | 1.000 | .998 | 15.04 | 4 | 157.75 | 172.81 | 236.08 | 80.09 |
| 1 | 1.000 | .986 | 15.11 | 3 | 169.33 | 171.11 | 218.85 | 74.64 |
| Mean | | .997 | 14.99 | | 146.54 | 172.337 | 235.698 | 80.437 |

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*Holyoke tests of Samson turbines*—Continued.

45-INCH RIGHT-HAND WHEEL—Continued.

| Number of tests. | Gate opening (proportional part). | Proportional discharge. (Discharge of full gate at highest efficiency=1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. | Horse-power developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 18 | 0.832 | 0.887 | 14.99 | 4 | 112.50 | 153.24 | 208.16 | 79.90 |
| 17 | .832 | .892 | 15.02 | 4 | 119.75 | 154.34 | 215.05 | 81.80 |
| 16 | 832 | .896 | 15.04 | 4 | 126.12 | 155.04 | 219.62 | 83.05 |
| 15 | .832 | .897 | 15.03 | 4 | 132.25 | 155.27 | 223.11 | 84.30 |
| 14 | .832 | .896 | 15.04 | 4 | 138.12 | 155.03 | 223.61 | 84.55 |
| 13 | .832 | .893 | 15.06 | 4 | 143.00 | 154.74 | 221.79 | 83.92 |
| 12 | .832 | .888 | 15.09 | 4 | 148.12 | 153.93 | 219.65 | 83.38 |
| 11 | .832 | .881 | 15.16 | 4 | 151.25 | 153.12 | 214.01 | 81.29 |
| 10 | .832 | .874 | 15.21 | 4 | 155.00 | 152.15 | 208.77 | 79.55 |
| 9 | .832 | .847 | 15.32 | 4 | 160.50 | 148.02 | 196.52 | 76.42 |
| Mean | | .885 | 15.10 | | 138.66 | 153.48 | 215.029 | 81.82 |
| 27 | .684 | .766 | 15.19 | 3 | 112.67 | 133.24 | 183.94 | 80.14 |
| 26 | .684 | .769 | 15.12 | 3 | 121.33 | 133.52 | 189.83 | 82.91 |
| 25 | .684 | 768 | 15.11 | 4 | 127.67 | 133.24 | 191.06 | 83.68 |
| 24 | .684 | .762 | 15.14 | 4 | 131.50 | 132.34 | 187.85 | 82.67 |
| 23 | .684 | .756 | 15.20 | 4 | 135.50 | 131.58 | 185.27 | 81.68 |
| 22 | .684 | .745 | 15.28 | 4 | 139.00 | 130.06 | 182.49 | 80.97 |
| 21 | .684 | .734 | 15.33 | 4 | 141.75 | 128.02 | 178.39 | 80.15 |
| 20 | .684 | .728 | 15.39 | 4 | 147.00 | 127.52 | 176.99 | 79.52 |
| 19 | .684 | .719 | 15.43 | 4 | 156.00 | 125.99 | 169.79 | 77.01 |
| Mean | | .749 | 15.24 | | 134.71 | 130.61 | 182.84 | 80.97 |
| 57 | .568 | .641 | 15.85 | 5 | 125.80 | 113.89 | 162.59 | 79.42 |
| 58 | .568 | .633 | 15.88 | 4 | 131.50 | 112.65 | 162.80 | 80.25 |
| 59 | .568 | .630 | 15.85 | 4 | 135.75 | 112.04 | 160.68 | 79.78 |
| 60 | .568 | .629 | 15.83 | 4 | 139.75 | 111.68 | 157.81 | 78.71 |
| 61 | .568 | .622 | 15.84 | 4 | 143.25 | 110.45 | 152.99 | 77.11 |
| 62 | .568 | .613 | 15.85 | 4 | 148.25 | 109.02 | 146.23 | 74.62 |
| Mean | | .628 | 15.85 | | 137.38 | 111.62 | 157.18 | 78.315 |
| 46 | .424 | .500 | 16.50 | 4 | 112.50 | 90.70 | 123.97 | 73.05 |
| 45 | .424 | .499 | 16.53 | 4 | 121.25 | 90.59 | 127.84 | 75.28 |
| 47 | .424 | .499 | 16.49 | 4 | 124.00 | 90.37 | 127.79 | 75.61 |
| 44 | .424 | .497 | 16.55 | 4 | 127.00 | 90.24 | 127.86 | 75.49 |
| 49 | .424 | .497 | 16.47 | 4 | 126.87 | 90.04 | 127.73 | 75.95 |
| 43 | .424 | .494 | 16.55 | 4 | 131.75 | 89.69 | 125.47 | 74.53 |
| 48 | .424 | .487 | 16.50 | 4 | 135.50 | 88.24 | 121.67 | 73.69 |
| 42 | .424 | .479 | 16.58 | 4 | 151.25 | 87.01 | 113.18 | 69.18 |
| Mean | | .495 | 16.52 | | 128.76 | 89.61 | 124.43 | 74.097 |

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*Holyoke tests of Samson turbines*—Continued.

56-INCH RIGHT-HAND WHEEL.

[Test No. 1257, June 20, 1900.]

| Number of tests. | Gate opening (proportional part). | Proportional discharge. (Discharge of full gate at highest efficiency = 1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. | Horse-power developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 19 | 1.000 | 0.995 | 13.27 | 3 | 99.67 | 245.41 | 303.28 | 82.29 |
| 18 | 1.000 | .996 | 13.27 | 4 | 104.00 | 245.75 | 307.27 | 83.26 |
| 17 | 1.000 | 1.001 | 13.27 | 4 | 108.62 | 246.86 | 309.85 | 83.58 |
| 16 | 1.000 | .999 | 13.30 | 4 | 111.75 | 246.69 | 307.40 | 82.79 |
| 15 | 1.000 | .992 | 13.33 | 4 | 113.50 | 245.26 | 302.19 | 81.68 |
| 14 | 1.000 | .980 | 13.50 | 4 | 117.00 | 243.81 | 294.03 | 78.94 |
| Mean | ..... | .994 | 13.32 | ..... | 109.09 | 245.63 | 304.00 | 82.09 |
| 25 | .919 | .945 | 13.52 | 4 | 99.37 | 235.43 | 301.69 | 83.75 |
| 24 | .919 | .947 | 13.50 | 4 | 104.25 | 235.56 | 304.47 | 84.60 |
| 23 | .919 | .943 | 13.52 | 4 | 107.75 | 234.80 | 301.52 | 83.93 |
| 22 | .919 | .936 | 13.56 | 4 | 110.12 | 233.37 | 295.43 | 82.50 |
| 21 | .919 | .928 | 13.63 | 4 | 112.37 | 231.98 | 288.50 | 80.63 |
| 20 | .919 | 916 | 13.71 | 4 | 115.12 | 229.82 | 281.48 | 78.94 |
| Mean | ..... | .936 | 13.57 | ..... | 108.16 | 233.49 | 295.51 | 82.39 |
| 32 | .846 | .885 | 13.80 | 4 | 96.62 | 222.77 | 293.34 | 84.32 |
| 31 | .846 | .888 | 13.79 | 4 | 101.00 | 223.37 | 296.35 | 85.01 |
| 30 | .846 | .882 | 13.80 | 4 | 103.12 | 221.99 | 292.06 | 84.24 |
| 29 | .846 | .876 | 13.82 | 4 | 105.00 | 220.47 | 286.69 | 83.14 |
| 28 | .846 | .868 | 13.91 | 5 | 107.80 | 219.26 | 283.35 | 82.10 |
| 27 | .846 | .855 | 14.09 | 4 | 110.87 | 217.31 | 278.62 | 80.41 |
| 26 | .846 | .843 | 14.11 | 4 | 113.50 | 214.58 | 269.81 | 78.75 |
| Mean | ..... | .871 | 13.90 | ..... | 105.41 | 219.96 | 285.74 | 82.567 |
| 54 | .771 | .824 | 14.15 | 4 | 97.50 | 210.02 | 282.77 | 84.08 |
| 53 | .771 | .819 | 14.18 | 4 | 100.37 | 208.95 | 280.18 | 83.56 |
| 52 | .771 | .812 | 14.21 | 4 | 102.12 | 207.29 | 274.66 | 82.40 |
| 51 | .771 | .802 | 14.24 | 4 | 104.00 | 205.01 | 269.13 | 81.46 |
| 50 | .771 | .794 | 14.27 | 4 | 106.25 | 203.03 | 264.12 | 80.56 |
| 49 | .771 | .786 | 14.33 | 3 | 109.67 | 201.51 | 260.71 | 79.78 |
| Mean | ..... | .806 | 14.23 | ..... | 103.31 | 205.96 | 271.92 | 81.97 |
| 48 | .696 | .736 | 14.63 | 4 | 97.50 | 190.73 | 254.95 | 80.74 |
| 47 | .696 | .727 | 14.69 | 4 | 100.37 | 188.70 | 254.28 | 81.06 |
| 46 | .696 | .725 | 14.70 | 4 | 103.75 | 188.28 | 253.68 | 80.99 |
| 45 | .696 | .717 | 14.76 | 4 | 106.87 | 186.67 | 250.42 | 80.31 |
| 44 | .696 | .715 | 14.81 | 4 | 110.50 | 186.38 | 247.67 | 79.29 |
| Mean | ..... | .724 | 14.72 | ..... | 103.798 | 188.15 | 252.20 | 80.478 |
| 43 | .626 | .663 | 15.11 | 4 | 98.25 | 174.50 | 238.90 | 80.06 |
| 42 | .626 | .660 | 15.12 | 4 | 102.00 | 173.83 | 239.01 | 80.36 |
| 41 | .626 | .655 | 15.16 | 4 | 105.00 | 172.83 | 236.77 | 79.85 |
| 40 | .626 | .651 | 15.13 | 4 | 107.37 | 171.55 | 231.17 | 78.70 |
| 39 | .626 | .647 | 15.17 | 4 | 110.75 | 170.70 | 225.66 | 77.01 |
| Mean | ..... | .655 | 15.14 | ..... | 104.67 | 172.68 | 234.30 | 79.196 |

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*Holyoke tests of Samson turbines*—Continued.

56-INCH RIGHT-HAND WHEEL—Continued.

| Number of tests. | Gate opening (proportional part). | Proportional discharge. (Discharge of full gate at highest efficiency=1.) | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. | Horsepower developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 38 | 0.564 | 0.603 | 15.45 | 4 | 95.50 | 160.63 | 219.89 | 78.29 |
| 37 | .564 | .600 | 15.44 | 4 | 98.62 | 159.54 | 218.36 | 78.33 |
| 36 | .564 | .598 | 15.46 | 4 | 102.25 | 159.11 | 217.37 | 78.09 |
| 35 | .564 | .592 | 15.49 | 4 | 105.75 | 157.75 | 214.04 | 77.40 |
| 34 | .564 | .587 | 15.51 | 4 | 109.87 | 156.65 | 208.95 | 75.99 |
| 33 | .564 | .581 | 15.56 | 4 | 114.00 | 155.30 | 201.31 | 73.62 |
| Mean | | .594 | 15.48 | | 104.33 | 158.16 | 213.32 | 76.95 |
| 6 | .497 | .537 | 15.91 | 4 | 101.25 | 145.14 | 195.99 | 75.00 |
| 5 | .497 | .532 | 15.95 | 4 | 105.12 | 143.93 | 192.77 | 74.20 |
| 4 | .497 | .527 | 16.00 | 5 | 109.20 | 142.87 | 189.13 | 73.11 |
| 3 | .497 | .522 | 16.04 | 4 | 113.37 | 141.70 | 184.80 | 71.85 |
| 2 | .497 | .520 | 16.04 | 4 | 117.50 | 140.91 | 179.56 | 70.20 |
| 1 | .497 | .517 | 16.07 | 4 | 125.75 | 140.27 | 170.82 | 66.96 |
| Mean | | .526 | 16.00 | | 112.03 | 142.47 | 185.51 | 71.88 |

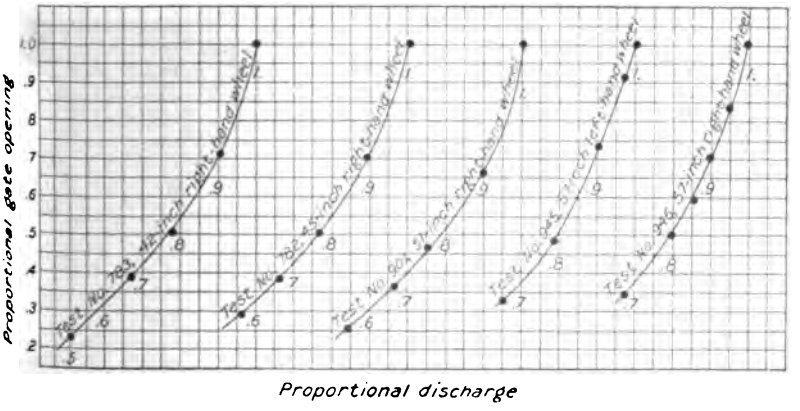


FIG. 27.—Proportional discharge coefficients for New American turbines.

HOLYOKE TESTS OF NEW AMERICAN AND SWAIN TURBINES.

The New American turbine has a modern large-capacity runner mounted in a pivoted-gate case. The runner resembles that of the Swain type of turbine, and bulges downward and outward less than those of the McCormick type of turbine.

Complete tests of three sizes of New American turbines have been published by the builders, the Dayton Globe Works, of Dayton, Ohio, and are presented in the following tables. The means of the various factors for each experimental gate opening and for each size of wheel have been computed and are included in the tables.

A recent test of a Swain turbine is appended.

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*Holyoke tests of New American turbines.*

42-INCH RIGHT-HAND WHEEL.

[Test No. 783, July 14, 1894.]

| Number. | Gate opening (proportional part). | Proportional discharge. (Discharge at full gate with highest efficiency=1.) | Mean head in feet. | Duration of tests in minutes. | Revolutions per minute. | Discharge in second-feet. | Horse-power developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 33 | 1.000 | 1.014 | 16.39 | 4 | 116.25 | 136.40 | 200.24 | 79.17 |
| 32 | 1.000 | 1.008 | 16.37 | 4 | 120.50 | 135.60 | 200.99 | 80.03 |
| 31 | 1.000 | 1.004 | 16.36 | 4 | 124.00 | 134.97 | 200.08 | 80.09 |
| 30 | 1.000 | .999 | 16.33 | 4 | 128.00 | 134.18 | 199.56 | 80.50 |
| 29 | 1.000 | .994 | 16.33 | 4 | 132.25 | 133.54 | 198.08 | 80.29 |
| 28 | 1.000 | .988 | 16.28 | 3 | 136.00 | 132.52 | 194.44 | 79.66 |
| Mean | | 1.001 | 16.34 | | 126.16 | 134.54 | 198.86 | 77.96 |
| 27 | .710 | .916 | 16.43 | 4 | 112.25 | 123.38 | 184.18 | 80.31 |
| 26 | .710 | .912 | 16.46 | 4 | 117.50 | 122.99 | 186.39 | 81.38 |
| 25 | .710 | .907 | 16.47 | 4 | 122.25 | 122.36 | 187.27 | 82.13 |
| 24 | .710 | .900 | 16.51 | 4 | 128.25 | 121.60 | 187.73 | 82.65 |
| 23 | .710 | .893 | 16.56 | 5 | 134.80 | 120.85 | 188.14 | 83.09 |
| 22 | .710 | .877 | 16.55 | 4 | 144.00 | 118.57 | 181.37 | 81.69 |
| Mean | | .903 | 16.50 | | 126.51 | 121.63 | 185.85 | 81.87 |
| 21 | .504 | .798 | 16.87 | 3 | 110.00 | 108.99 | 164.76 | 79.20 |
| 20 | .504 | .795 | 16.74 | 3 | 113.33 | 108.15 | 164.34 | 80.24 |
| 19 | .504 | .793 | 16.53 | 5 | 117.00 | 107.18 | 163.29 | 81.47 |
| 18 | .504 | .785 | 16.56 | 4 | 124.00 | 106.25 | 164.62 | 82.70 |
| 17 | .504 | .774 | 16.59 | 3 | 129.33 | 104.85 | 162.89 | 82.77 |
| 16 | .504 | .764 | 16.67 | 4 | 133.75 | 103.67 | 159.35 | 81.50 |
| 15 | .504 | .736 | 16.77 | 4 | 141.75 | 100.20 | 149.58 | 78.68 |
| Mean | | .778 | 16.68 | | 124.17 | 105.61 | 161.26 | 80.94 |
| 14 | .389 | .700 | 17.10 | 4 | 106.00 | 96.17 | 140.73 | 75.64 |
| 13 | .389 | .697 | 17.04 | 3 | 113.33 | 95.58 | 144.28 | 78.30 |
| 12 | .389 | .685 | 17.11 | 4 | 120.25 | 94.22 | 144.91 | 79.45 |
| 11 | .389 | .674 | 17.13 | 4 | 125.25 | 92.76 | 142.40 | 79.21 |
| 10 | .389 | .660 | 17.15 | 4 | 130.00 | 90.85 | 138.96 | 78.83 |
| 9 | .389 | .646 | 17.20 | 4 | 136.00 | 89.10 | 134.26 | 77.43 |
| 8 | .389 | .633 | 17.25 | 4 | 144.50 | 87.44 | 127.89 | 74.94 |
| Mean | | .671 | 17.14 | | 125.05 | 92.30 | 139.06 | 77.69 |
| 7 | .230 | .530 | 17.42 | 4 | 102.62 | 73.51 | 100.61 | 69.44 |
| 6 | .230 | .527 | 17.44 | 4 | 108.50 | 73.10 | 101.20 | 70.16 |
| 5 | .230 | .520 | 17.48 | 4 | 113.25 | 72.27 | 100.23 | 70.13 |
| 4 | .230 | .509 | 17.48 | 4 | 121.00 | 70.80 | 98.85 | 70.60 |
| 3 | .230 | .501 | 17.48 | 4 | 128.75 | 69.66 | 96.42 | 69.99 |
| 2 | .230 | .494 | 17.51 | 5 | 136.20 | 68.73 | 92.73 | 68.10 |
| Mean | | .514 | 17.47 | | 118.39 | 71.34 | 98.34 | 69.74 |

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*Holyoke tests of New American turbines*—Continued.

45-INCH RIGHT-HAND WHEEL.

[Test No. 782, July 9, 1894.]

| Number. | Gate opening (proportional part). | Proportional discharge. (Discharge at full gate with highest efficiency = 1). | Mean head in feet. | Duration of tests in minutes. | Revolutions per minute. | Discharge in second-feet. | Horse-power developed. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 37 | 1.000 | 1.022 | 15.98 | 4 | 103.50 | 144.87 | 205.05 | 78.26 |
| 36 | 1.000 | 1.015 | 16.01 | 4 | 107.50 | 143.95 | 205.66 | 78.84 |
| 35 | 1.000 | 1.009 | 16.02 | 3 | 112.00 | 143.17 | 206.64 | 79.60 |
| 34 | 1.000 | 1.003 | 16.04 | 4 | 115.37 | 142.36 | 205.79 | 79.63 |
| 33 | 1.000 | .997 | 16.06 | 3 | 119.17 | 141.58 | 205.27 | 79.76 |
| 32 | 1.000 | .990 | 16.09 | 4 | 123.00 | 140.77 | 203.49 | 79.38 |
| 31 | 1.000 | .983 | 16.13 | 4 | 127.75 | 140.02 | 200.04 | 78.26 |
| Mean | | 1.003 | 16.05 | | 115.47 | 142.39 | 204.56 | 79.10 |
| 30 | .699 | .921 | 16.30 | 4 | 101.25 | 131.77 | 195.08 | 80.25 |
| 29 | .699 | .914 | 16.38 | 4 | 105.75 | 131.12 | 197.27 | 81.15 |
| 28 | .699 | .905 | 16.40 | 4 | 110.25 | 129.93 | 198.16 | 82.17 |
| 27 | .699 | .899 | 16.41 | 4 | 113.87 | 129.11 | 197.69 | 82.44 |
| 26 | .699 | .893 | 16.42 | 3 | 117.33 | 128.35 | 196.51 | 82.38 |
| 25 | .699 | .885 | 16.42 | 4 | 122.00 | 127.18 | 195.19 | 82.58 |
| 24 | .699 | .874 | 16.45 | 4 | 127.50 | 125.67 | 190.97 | 81.62 |
| 23 | .699 | .856 | 16.53 | 3 | 134.00 | 123.42 | 182.46 | 79.02 |
| Mean | | .893 | 16.41 | | 116.49 | 128.32 | 194.17 | 81.45 |
| 22 | .505 | .800 | 16.68 | 4 | 102.00 | 115.77 | 175.69 | 80.39 |
| 21 | .505 | .796 | 16.71 | 3 | 106.00 | 115.29 | 176.81 | 81.09 |
| 20 | .505 | .787 | 16.74 | 4 | 110.75 | 114.17 | 177.19 | 81.92 |
| 19 | .505 | .775 | 16.78 | 3 | 117.33 | 112.60 | 175.74 | 82.18 |
| 18 | .505 | .762 | 16.81 | 4 | 122.50 | 110.81 | 170.97 | 81.10 |
| 17 | .505 | .746 | 16.85 | 5 | 127.40 | 108.50 | 164.80 | 79.64 |
| 16 | .505 | .725 | 16.86 | 4 | 133.50 | 105.56 | 154.51 | 76.71 |
| Mean | | .770 | 16.78 | | 117.07 | 111.81 | 170.82 | 80.43 |
| 15 | .382 | .687 | 16.97 | 4 | 101.25 | 100.29 | 149.58 | 77.66 |
| 14 | .382 | .681 | 17.00 | 4 | 107.00 | 99.50 | 150.79 | 78.77 |
| 13 | .382 | .671 | 17.03 | 3 | 111.83 | 98.12 | 149.99 | 79.31 |
| 12 | .382 | .661 | 17.07 | 4 | 116.00 | 96.83 | 147.68 | 78.94 |
| 11 | .382 | .651 | 17.11 | 4 | 119.75 | 95.48 | 144.30 | 78.05 |
| 10 | .382 | .635 | 17.19 | 4 | 127.50 | 93.32 | 138.89 | 76.50 |
| Mean | | .664 | 17.09 | | 113.89 | 97.26 | 146.87 | 78.21 |
| 8 | .293 | .584 | 16.84 | 4 | 99.25 | 84.91 | 120.28 | 74.32 |
| 7 | .293 | .579 | 16.83 | 3 | 103.33 | 84.27 | 120.30 | 74.94 |
| 6 | .293 | .572 | 16.86 | 3 | 108.00 | 83.28 | 119.85 | 75.42 |
| 5 | .293 | .563 | 16.88 | 3 | 118.67 | 82.07 | 118.40 | 75.52 |
| 4 | .293 | .553 | 16.90 | 3 | 119.67 | 80.54 | 114.06 | 74.04 |
| 3 | .293 | .541 | 16.94 | 4 | 127.00 | 78.93 | 108.08 | 71.42 |
| Mean | | .565 | 16.87 | | 112.65 | 82.33 | 116.83 | 74.28 |

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*Holyoke tests of New American turbines*—Continued.

51-INCH RIGHT-HAND WHEEL.

[Test No. 901, March 11-12, 1896.]

| Number. | Gate opening (proportional part). | Proportional discharge. (Discharge at full gate with highest efficiency = 1). | Mean head in feet. | Duration of tests in minutes. | Revolutions per minute. | Discharge in second-feet. | Horse-power developed. | Percentage of efficiency |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 42 | 1.000 | 1.021 | 14.83 | 5 | 84.20 | 195.90 | 255.10 | 77. |
| 41 | 1.000 | 1.016 | 14.88 | 4 | 88.50 | 195.30 | 259.09 | 78.( |
| 40 | 1.000 | 1.010 | 14.88 | 5 | 91.70 | 194.24 | 259.09 | 79.( |
| 43 | 1.000 | 1.007 | 14.87 | 4 | 93.50 | 193.52 | 259.08 | 79.3 |
| 39 | 1.000 | 1.005 | 14.94 | 4 | 95.62 | 193.65 | 260.40 | 79.3 |
| 44 | 1.000 | 1.003 | 14.86 | 5 | 96.80 | 192.78 | 258.34 | 79.( |
| 38 | 1.000 | .999 | 15.03 | 6 | 100.00 | 192.94 | 262.11 | 79.7 |
| 37 | 1.000 | .991 | 15.13 | 4 | 103.25 | 192.08 | 260.09 | 78.9 |
| 45 | 1.000 | .988 | 14.94 | 4 | 104.87 | 190.34 | 253.46 | 78.5 |
| Mean | | 1.004 | 14.93 | | 95.38 | 193.42 | 258.53 | 78.9 |
| 36 | .659 | .916 | 15.39 | 4 | 85.50 | 179.12 | 251.47 | 80.4 |
| 35 | .659 | .911 | 15.40 | 4 | 89.12 | 178.10 | 253.01 | 81.3 |
| 34 | .659 | .905 | 15.43 | 5 | 92.80 | 177.11 | 253.98 | 81.9 |
| 33 | .659 | .898 | 15.46 | 4 | 96.75 | 175.98 | 254.91 | 82.6 |
| 32 | .659 | .891 | 15.49 | 4 | 100.25 | 174.85 | 252.53 | 82.21 |
| 31 | .659 | .882 | 15.50 | 4 | 104.50 | 173.16 | 249.01 | 81.8 |
| Mean | | .9005 | 15.44 | | 94.82 | 176.39 | 252.48 | 81.72 |
| 30 | .465 | .806 | 15.88 | 4 | 79.75 | 160.00 | 223.15 | 77.44 |
| 29 | .465 | .802 | 15.95 | 4 | 85.33 | 159.70 | 230.05 | 79.63 |
| 28 | .465 | .794 | 16.09 | 5 | 90.60 | 158.74 | 235.01 | 81.13 |
| 27 | .465 | .788 | 16.04 | 5 | 93.40 | 157.23 | 232.73 | 81.37 |
| 26 | .465 | .781 | 15.96 | 4 | 96.25 | 155.60 | 230.01 | 81.66 |
| 25 | .465 | .774 | 15.97 | 5 | 99.10 | 154.26 | 226.70 | 81.14 |
| 24 | .465 | .763 | 16.05 | 5 | 102.60 | 152.36 | 222.13 | 80.09 |
| 23 | .465 | .751 | 16.12 | 5 | 106.20 | 150.36 | 216.91 | 78.91 |
| 22 | .465 | .730 | 16.42 | 3 | 112.00 | 147.43 | 209.69 | 76.38 |
| Mean | | .754 | 16.05 | | 96.14 | 155.08 | 225.15 | 79.75 |
| 21 | .362 | .700 | 16.43 | 4 | 80.25 | 141.35 | 196.69 | 74.67 |
| 20 | .362 | .696 | 16.44 | 4 | 86.50 | 140.59 | 203.17 | 77.51 |
| 19 | .362 | .689 | 16.44 | 4 | 90.00 | 139.25 | 202.20 | 77.88 |
| 18 | .362 | .681 | 16.50 | 4 | 93.75 | 137.97 | 201.05 | 77.87 |
| 17 | .362 | .673 | 16.56 | 4 | 97.25 | 136.40 | 198.63 | 77.54 |
| 16 | .362 | .662 | 16.59 | 4 | 100.25 | 134.33 | 194.52 | 76.96 |
| 15 | .362 | .651 | 16.67 | 4 | 103.25 | 132.40 | 189.80 | 75.82 |
| 14 | .362 | .643 | 16.70 | 4 | 106.50 | 130.89 | 184.90 | 74.58 |
| 18 | .362 | .633 | 16.74 | 4 | 111.25 | 128.98 | 179.51 | 73.30 |
| 12 | .362 | .620 | 16.79 | 4 | 117.50 | 126.70 | 167.99 | 69.63 |
| Mean | | .665 | 16.59 | | 98.65 | 134.88 | 191.85 | 75.58 |
| 11 | .251 | .559 | 17.03 | 4 | 82.50 | 115.02 | 155.58 | 70.03 |
| 10 | .251 | .556 | 17.00 | 4 | 85.50 | 114.31 | 155.42 | 70.52 |
| 9 | .251 | .551 | 17.02 | 4 | 88.50 | 113.20 | 154.85 | 70.87 |
| 8 | .251 | .544 | 17.06 | 4 | 92.00 | 111.98 | 154.71 | 71.40 |
| 7 | .251 | .537 | 17.10 | 4 | 96.25 | 110.76 | 153.99 | 71.69 |
| 6 | .251 | .531 | 17.10 | 4 | 100.00 | 109.44 | 149.78 | 70.53 |
| 5 | .251 | .529 | 17.10 | 4 | 101.50 | 109.08 | 148.57 | 70.27 |
| Mean | | .544 | 17.06 | | 92.32 | 111.97 | 153.27 | 70.74 |

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*Holyoke tests of Swain turbines.*[a]

36-INCH RIGHT-HAND WHEEL.

[Test No. 977, January 20-21, 1897.]

| Number. | Gate opening (decimal part). | Discharge (decimal part). | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge in second-feet. | Developed horse-power. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 64 | 1.000 | 1.004 | 15.16 | 3 | 130.33 | 76.49 | 111.57 | 84.84 |
| 63 | 1.000 | .995 | 15.25 | 4 | 135.00 | 75.98 | 111.47 | 84.83 |
| 62 | 1.000 | .984 | 15.40 | 3 | 140.33 | 75.52 | 111.61 | 84.62 |
| 61 | 1.000 | .973 | 15.42 | 3 | 144.00 | 74.74 | 110.16 | 84.28 |
| 60 | 1.000 | .966 | 15.43 | 4 | 146.50 | 74.19 | 108.51 | 83.58 |
| 59 | 1.000 | .954 | 15.48 | 4 | 150.75 | 73.45 | 107.08 | 83.04 |
| 58 | 1.000 | .945 | 15.47 | 4 | 154.00 | 72.73 | 104.72 | 82.07 |
| 57 | 1.000 | .934 | 15.44 | 3 | 158.00 | 71.76 | 101.68 | 80.92 |
| 56 | 1.000 | .922 | 15.33 | 4 | 161.37 | 70.58 | 97.97 | 79.84 |
| Mean | | .964 | 15.38 | | 146.70 | 73.94 | 107.20 | 83.11 |
| 55 | .875 | .932 | 15.16 | 3 | 132.00 | 70.95 | 102.58 | 84.10 |
| 54 | .875 | .925 | 15.15 | 4 | 135.75 | 70.42 | 102.20 | 84.47 |
| 53 | .875 | .916 | 15.28 | 4 | 140.75 | 70.01 | 102.54 | 84.52 |
| 52 | .875 | .907 | 15.41 | 4 | 147.00 | 69.61 | 102.63 | 84.37 |
| 51 | .875 | .896 | 15.50 | 4 | 153.50 | 68.99 | 101.58 | 83.75 |
| 50 | .875 | .877 | 15.60 | 3 | 162.33 | 67.75 | 98.55 | 82.22 |
| Mean | | .909 | 15.35 | | 145.22 | 69.62 | 101.68 | 83.91 |
| 49 | .750 | .866 | 15.66 | 4 | 130.00 | 67.03 | 100.24 | 84.20 |
| 48 | .750 | .857 | 15.74 | 4 | 136.00 | 66.52 | 100.73 | 84.83 |
| 47 | .750 | .849 | 15.76 | 4 | 141.00 | 65.96 | 100.16 | 84.96 |
| 46 | .750 | .844 | 15.70 | 2 | 146.00 | 65.41 | 99.28 | 85.24 |
| 45 | .750 | .838 | 15.54 | 4 | 149.75 | 64.64 | 97.28 | 85.39 |
| 44 | .750 | .829 | 15.62 | 3 | 157.33 | 64.09 | 96.47 | 84.97 |
| 43 | .750 | .826 | 15.16 | 4 | 156.75 | 62.88 | 91.36 | 84.51 |
| 42 | .750 | .814 | 15.20 | 4 | 162.75 | 62.06 | 88.93 | 83.13 |
| Mean | | .840 | 15.55 | | 147.45 | 64.82 | 96.81 | 84.65 |
| 41 | .625 | .783 | 15.30 | 4 | 127.50 | 59.90 | 85.92 | 82.67 |
| 40 | .625 | .775 | 15.38 | 4 | 134.75 | 59.45 | 86.72 | 83.63 |
| 39 | .625 | .767 | 15.43 | 4 | 142.12 | 58.95 | 87.15 | 84.48 |
| 38 | .625 | .758 | 15.47 | 4 | 149.50 | 58.30 | 86.23 | 84.30 |
| 37 | .625 | .749 | 15.51 | 4 | 154.50 | 57.70 | 84.42 | 83.18 |
| 36 | .625 | .733 | 15.58 | 4 | 162.75 | 56.62 | 81.02 | 80.99 |
| 35 | .625 | .715 | 15.65 | 4 | 169.50 | 55.32 | 76.15 | 77.56 |
| Mean | | .754 | 15.50 | | 148.66 | 58.03 | 83.95 | 82.40 |
| 34 | .500 | .683 | 15.74 | 5 | 123.20 | 52.98 | 74.80 | 79.09 |
| 33 | .500 | .676 | 15.78 | 4 | 131.25 | 52.54 | 75.70 | 80.51 |
| 32 | .500 | .668 | 15.83 | 4 | 137.50 | 51.98 | 75.13 | 80.51 |
| 31 | .500 | .660 | 15.85 | 4 | 144.00 | 51.42 | 74.31 | 80.40 |
| 30 | .500 | .652 | 15.91 | 4 | 150.25 | 50.87 | 72.98 | 79.51 |
| 29 | .500 | .644 | 15.95 | 4 | 157.50 | 50.31 | 71.72 | 78.81 |
| 28 | .500 | .635 | 15.96 | 3 | 163.33 | 49.62 | 69.41 | 77.29 |
| Mean | | .660 | 15.86 | | 143.86 | 51.39 | 73.44 | 79.44 |

[a] Made by Swain Turbine and Manufacturing Company, Lowell, Mass.

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*Holyoke tests of Swain turbines*—Continued.

36-INCH RIGHT-HAND WHEEL—Continued.

| Number. | Gate opening (decimal part). | Discharge (decimal part). | Mean head in feet. | Duration of test in minutes. | Revolutions per minute. | Discharge, in second-feet. | Developed horse-power. | Percentage of efficiency. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 26 | 0.375 | 0.557 | 15.21 | 4 | 120.37 | 42.50 | 54.08 | 73.77 |
| 25 | .375 | .552 | 15.19 | 4 | 127.50 | 42.06 | 54.19 | 74.75 |
| 24 | .375 | .545 | 15.21 | 4 | 133.50 | 41.58 | 53.49 | 74.56 |
| 23 | .375 | .538 | 15.21 | 4 | 139.00 | 41.06 | 52.32 | 73.47 |
| 22 | .375 | .531 | 15.22 | 3 | 145.67 | 40.53 | 51.30 | 73.22 |
| 21 | .375 | .524 | 15.21 | 3 | 152.33 | 40.01 | 49.94 | 72.38 |
| 20 | .375 | .514 | 15.30 | 4 | 160.25 | 39.36 | 48.65 | 71.23 |
| 27 | .375 | .504 | 15.30 | 5 | 167.20 | 38.57 | 45.68 | 68.25 |
| Mean | | .533 | 15.23 | | 143.23 | 40.71 | 51.21 | 72.77 |
| 19 | .250 | .420 | 15.53 | 4 | 113.50 | 32.40 | 36.52 | 64.01 |
| 18 | .250 | .416 | 15.54 | 4 | 120.25 | 32.11 | 36.50 | 64.57 |
| 17 | .250 | .412 | 15.57 | 4 | 126.50 | 31.83 | 36.10 | 64.27 |
| 16 | .250 | .407 | 15.61 | 4 | 133.25 | 31.46 | 35.60 | 63.91 |
| 15 | .250 | .401 | 15.60 | 4 | 139.50 | 31.00 | 34.72 | 63.11 |
| 14 | .250 | .396 | 15.61 | 4 | 146.25 | 30.59 | 33.74 | 62.11 |
| 13 | .250 | .386 | 15.66 | 4 | 155.75 | 29.91 | 32.15 | 60.32 |
| 12 | .250 | .378 | 15.70 | 4 | 163.50 | 29.26 | 29.78 | 57.16 |
| 11 | .250 | .367 | 15.74 | 4 | 171.75 | 28.45 | 26.07 | 51.33 |
| 10 | .250 | .356 | 15.79 | 4 | 179.50 | 27.64 | 21.80 | 44.04 |
| Mean | | .394 | 15.64 | | 144.98 | 30.46 | 32.30 | 59.53 |
| 9 | .125 | .257 | 16.03 | 4 | 111.50 | 20.06 | 16.92 | 46.40 |
| 8 | .125 | .254 | 16.01 | 4 | 119.00 | 19.89 | 16.62 | 46.02 |
| 7 | .125 | .252 | 16.07 | 4 | 126.75 | 19.76 | 16.16 | 44.85 |
| 6 | .125 | .249 | 16.17 | 4 | 134.12 | 19.62 | 15.47 | 43.31 |
| 5 | .125 | .247 | 16.23 | 4 | 141.00 | 19.45 | 14.55 | 40.67 |
| 4 | .125 | .245 | 16.18 | 4 | 146.25 | 19.24 | 13.32 | 37.77 |
| 3 | .125 | .242 | 16.22 | 4 | 152.25 | 19.07 | 12.02 | 34.21 |
| 2 | .125 | .239 | 16.11 | 4 | 159.50 | 18.73 | 9.68 | 28.11 |
| Mean | | .248 | 16.13 | | 123.80 | 19.48 | 14.34 | 40.19 |
| 1 | .067 | .161 | 16.49 | 4 | 153.25 | 12.80 | | |

## THE USE OF THE TURBINE AS A WATER METER.

In conjunction with the stream-gaging operations of the United States Geological Survey in New York and the New England States the method of utilizing existing dams as weirs and of determining the flow through turbines by using them as meters has been found convenient in many instances.

It not infrequently happens that nearly the entire fall of a stream is taken up at existing dams, leaving no opportunity for gaging by floats or current meter in open section without encountering backwater. In rapid, precipitous streams the current may be so rough as to render open section measurements unfeasible without great expense for preparation.

The use of the turbine as a water meter, as well as a water motor, has been most elaborately carried out at Holyoke, where about 150 turbines are used in 50 mills. They have all been accurately calibrated in the testing flume, and the amount of water used and to

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be paid for by the different companies is ascertained from daily observations of the head and speed-gate opening.

A similar method of stream measurement has been in use at Mechanicsville, N. Y., on the Hudson River, beginning in 1888, under the direction of R. P. Bloss. In 1891-92 stream gagings at dams and mills were extensively carried out in New Jersey by C. C. Vermeule, and in 1898 a number of such gaging stations were established in New York by George W. Rafter. At the present time many gaging stations at dams and mills are maintained in the Great Lakes and New England districts by the United States Geological Survey. It is found that continuous gaging records can often be maintained summer and winter in this way where other methods would not be feasible owing to obstruction of the streams by ice.

In some cases the identical turbines used in the mills have been tested at Holyoke, but in the majority of cases dependence must be placed upon tests of wheels from the same patterns. Where these are not available tests of wheels of the same make but of different sizes may be used to determine the proper discharge coefficients, or, in the absence of all tests, the manufacturer's rating tables may be used as a guide in calibrating the turbines. (For discussion of such tables, see p. 87.)

In connection with the use of the turbine as a water meter various questions arise relative to the accuracy attainable under different conditions.

### RELIABILITY OF HOLYOKE TESTS AS TO TURBINE DISCHARGE.

Tests made by the writer indicate very close agreement between tested and actual discharge. This is confirmed by other unpublished tests which have been examined.

In general it may be said that whereas local conditions may cause considerable departure from the test in regard to power and speed, the discharge will remain fairly constant unless the turbine is in so cramped a position as to partially shut off free access of the water supply to the wheel. The above statements also apply to the agreement between manufacturer's rating tables and wheels in actual use, in cases where the rating tables have been deduced from authentic tests.

The following figures for flow measured by a turbine and by a current meter at gaging stations were obtained without special precautions, conditions being the same as for the regular gaging record. They may be taken as representing what may ordinarily be expected, the fact being borne in mind that a part of the difference between the turbine and current meter measurements may be attributed to errors of the meter measurements.

*Comparison of discharge measurements made by means of turbine and current meter.*

| | |
|---|---|
| **Middleville, N. Y., March 28, 1901, head 8.25 feet.** | |
| Turbine measurement: | |
| 66-inch Leffel, full gate | 105 |
| 21-inch Camden, full gate | 14.4 |
| 36-inch Camden, 0.75 gate | 36 |
| Waste weir | 6.4 |
| Total | 161.8 |
| Current-meter measurement in headrace | 160.0 |
| **Middleville, N. Y., September 10, 1900, head 10 feet.** | |
| Turbine measurement: | |
| 66-inch Leffel, full gate | 115.0 |
| 21-inch Camden, full gate | 16.0 |
| Total | 131.0 |
| Current-meter measurement | 132.3 |
| **Schoharie Falls, N. Y., April 5, 1901, head 35.61 feet.** | |
| Turbine measurement: | |
| Pair Leffel-Samson 40-inch horizontal turbines, average gate, 0.449 | 210 |
| Current-meter measurement[a] in headrace | 216 |

[a] A slight loss by leakage occurred between point of measurement and the power house, probably about 2 second-feet.

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Little Falls, N. Y., Paper Company's mill, head 12.25 feet.

| | |
|---|---|
| Turbine measurement: | |
| 60-inch Camden, approximately 0.75 gate | 129 |
| 42-inch Camden, 0.75 gate | 55 |
| 36-inch Camden, 0.75 gate | 44 |
| Reddy turbines, 0.75 gate | 60 |
| Total | 288 |
| Current-meter measurement in headrace | 302 |

Mechanicsville, N. Y., October 20, 1900.

| | |
|---|---|
| Turbine measurement | 1,977 |
| Current-meter measurement[a] | 1,871 |

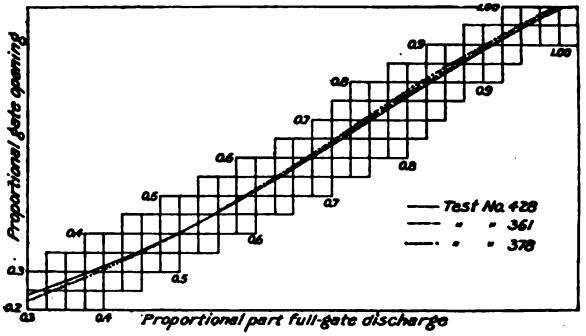


FIG. 28.—Part-gate discharge coefficients for three 24-inch Hercules turbines, showing close agreement of duplicate wheels from the same patterns.

## VARIATION IN DISCHARGE FOR DIFFERENT WHEELS OF SAME PATTERN.

For the best modern wheels having guide and bucket openings made to conform with standard gages, wheels from the same patterns will be found to agree closely as to discharge. This is illustrated by fig. 28, showing part-gate coefficient for three 24-inch Hercules turbines.

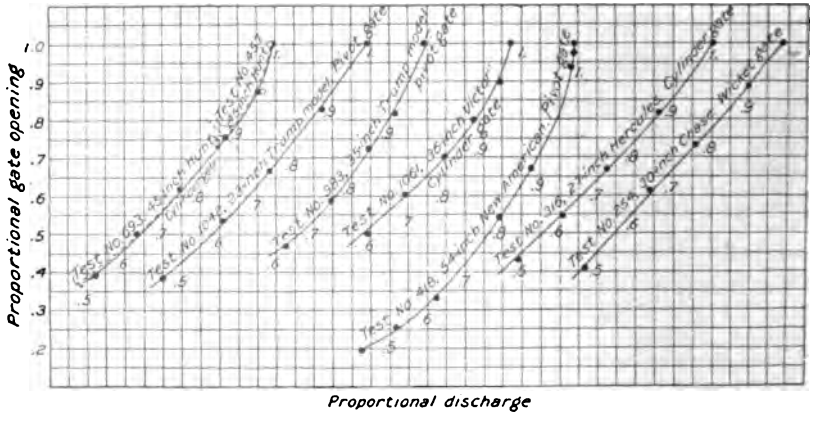


FIG. 29.—Types of part-gate discharge coefficient curves.

[a] Probably too small; slackwater. Very unsatisfactory meter measurement. The flow through individual turbines in this mill has been checked by the engineer and found to agree within 2 or 3 per cent with maker's tables.

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### VARIATION IN DISCHARGE FOR DIFFERENT WHEELS OF THE SAME TYPE.

Each type of runner and speed gate has its own characteristic part-gate discharge coefficient curve. Fig. 29 shows a series of such curves for various types of wheels with cylinder, pivot, and other forms of gate. As a rule, the part-gate coefficient curve is slightly concave upward. The discharge for one-half gate usually exceeds one-half of that of the full gate, while the discharge from three-fourths to full gate is often nearly proportional to the gate opening.

The various sizes of patterns of the principal builders resemble one another very closely. It will be found (see pp. 94–125) that the power, speed, and discharge of the various sizes are very nearly mathematical functions of the diameter.

The characteristic part-gate coefficient curve for any type of wheel is usually persistent for all sizes, within narrow limits of variation. Figs. 20 to 23 (on pp. 41–42) show part-gate discharge coefficient curves for various sized McCormick turbines from 12 to 57 inches diameter. With the exception of the 54-inch wheel, the curves for the different diameters resemble one another closely.

Taking the coefficients for various gate openings from the diagram, we obtain the following table:

*Part-gate discharge coefficients for McCormick turbines.*

| Diameter of wheel. | Full gate. | Three-fourths gate. | One-half gate. | Diameter of wheel. | Full gate. | Three-fourths gate. | One-half gate. |
|---|---|---|---|---|---|---|---|
| *Inches.* | | | | *Inches.* | | | |
| 12 | 1.000 | 0.855 | 0.660 | 39 | 0.988 | 0.845 | 0.628 |
| 15 | 1.000 | .868 | .666 | 42 | .993 | .830 | .628 |
| 18 | 1.012 | .888 | .695 | 45 | 1.005 | .868 | .655 |
| 21 | 1.005 | .866 | .655 | 48 | .980 | .838 | .610 |
| 24 | .998 | .864 | .655 | 51 | 1.006 | .840 | .625 |
| 27 | 1.006 | .855 | .645 | 57 | 1.005 | .864 | .652 |
| 30 | .970 | .850 | .642 | | | | |
| 33 | .998 | .860 | .638 | Average.... | .998 | .8574 | .6484 |
| 36 | 1.006 | .870 | .672 | | | | |

It will be seen that the departure from the average does not exceed 5 per cent for either the one-half or three-fourths gate coefficients for any of the sizes tested. This variation is due, at least in part, to the fact that the different wheels were not all tested over the same range of loads and speeds. The coefficients given are the averages for the loads and speeds included in the test at a given gate opening. These cover the range of variation likely to occur in ordinary practice.

*Part-gate discharge coefficients for Hercules, Leffel-Samson, and New American turbines.*

HERCULES.

| Diameter of wheel. | Full gate. | Three-fourths gate. | One-half gate. |
|---|---|---|---|
| *Inches.* | | | |
| 42 | 0.960 | 0.847 | 0.612 |
| 45 | .969 | .842 | .598 |
| 51 | .994 | .834 | .598 |
| | .9685 | .834 | .600 |
| 54 | .976 | .815 | .574 |

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*Part-gate discharge coefficients for Hercules, Leffel-Samson, and New American turbines*—Co

LEFFEL-SAMSON.

| Diameter of wheel. | Full gate. | Three-fourths gate. | One-half gate. |
|---|---|---|---|
| *Inches.* | | | |
| 23 | 0.995 | 0.82 | 0.58 |
| 35 | .995 | .78 | .535 |
| 45 | .995 | .81 | .56 |
| 56 | .995 | .785 | .535 |
| Average... | .995 | .799 | .552 |

NEW AMERICAN.

| | | | |
|---|---|---|---|
| 42 | 1.001 | 0.924 | 0.768 |
| 45 | 1.003 | .920 | .768 |
| 51 | 1.004 | .940 | .790 |
| 57 | 1.003 | .914 | .796 |
| 57 | .998 | .922 | .795 |

## VARIATION OF TURBINE DISCHARGE WITH SPEED.

Holyoke tests show that a turbine gives maximum efficiency for each gate opening under some certain speed. Considering the peripheral speed as a percentage of the spouting velocity due to the head, the following ratios are found for maximum efficiency for the Hercules turbine, results of tests of which are shown in figs. 15 to 19.

*Peripheral speed for maximum efficiency, various gate openings.—Hercules turbines.*

| Gate opening. | Ratio of peripheral velocity to velocity due to head. |
|---|---|
| Full. | 0.675 |
| 0.806 | .652 |
| .647 | .642 |
| .489 | .603 |
| .379 | .585 |

It will be seen that the speed of maximum efficiency decreases slowly with decreased gate opening. A turbine should be geared to drive the machinery to which is connected at a proper speed when the turbine is running at its speed of maximum efficiency for the gate opening at which it is commonly operated. If a turbine is running above or below its normal speed for a given head and gate opening its discharge will vary from that given in the maker's tables. In using the turbine as a water meter it is important that the normal speed at which the wheel runs under load should be known. The amount of variation in discharge resulting from varying the load and speed, the head remaining constant, is shown in figs. 30, 31, 32, which give speed-discharge curves for three sizes of Smith-McCormick turbines. A similar analysis of the effect of variation in load and speed can be made for other sizes and types of turbines from the data furnished by Holyoke tests, given on pages 43–76.

For the ordinary range of speed variation the discharge at a given gate opening usually decreases as the load decreases or as the speed increases. An overloaded turbine will, as a rule, use more water than one running at its normal load under the same head and gate opening. Turbines may be so constructed that the quantity of water discharged attains a maximum for each head and gate opening when running under a certain load. For loads either less or greater the discharge and power will decrease.

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The amount of variation in discharge corresponding to a given range of variation in speed is usually a maximum at full gate, decreasing as the gate opening is decreased. The amount of variation in full-gate discharge resulting from such variations in speed as will usually be allowable in practice is ordinarily small. This is illustrated by the following table.

*Variation in full-gate discharge with varying speed, Smith-McCormick turbines.*

| Wheel. | Range in speed. | Corresponding variations in discharge. |
|---|---|---|
| | *Revolutions per minute.* | *Per cent.* |
| 24-inch | 178 to 231 | 2.8 |
| 42-inch | 123 to 146 | 3.3 |
| 54-inch | 81 to 110 | 3.4 |

For the turbines considered in the above table a variation of 25 per cent in the speed at full gate will cause a variation but little exceeding 3 per cent in the discharge. If a turbine runs normally at its tabled speed, and variations in excess or deficiency are equally likely to occur, their effect on discharge may commonly be neglected in using the turbine as a water meter.

Turbines controlled by automatic governors often afford favorable opportunities for recording the discharge. Care should always be taken to eliminate slip of the turbine gate mechanism and to have the governor gate indicator so set that its indications correspond with the actual proportional opening of the turbine gates. A scale attached directly to the turbine gate cylinder or gate stem and graduated by trial may often be used. It should indicate zero when waste motion in the mechanism has just been taken up and full gate at such a point that any further opening does not increase the area of the inlet ports.

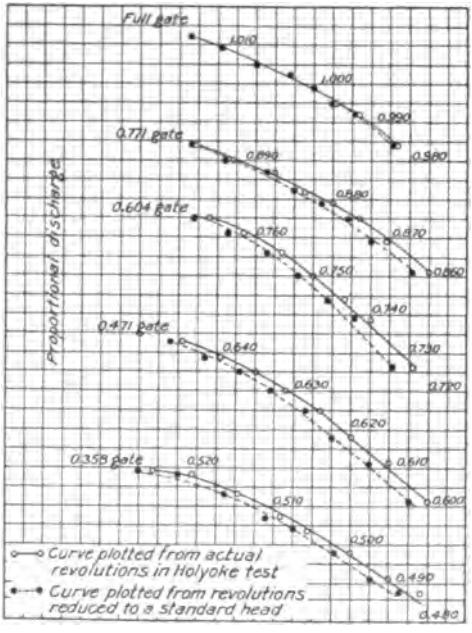


FIG. 30.—Variation of turbine discharge with speed, 24-inch McCormick turbine.

## VARIATION OF TURBINE COEFFICIENTS WITH VARIATION IN HEAD.

The discharge coefficients for heads corresponding with those used in making tests at the Holyoke flume are known with considerable accuracy.

In the use of the turbine as a water meter, where the wheels are installed under heads either greater or less than those used at the Holyoke flume, the question arises as to the applicability of the discharge coefficients. Data of tests by James Emerson (p. 30) indicate that the coefficients of discharge through turbine buckets and guides, considered as orifices, are very nearly constant for ordinary heads.



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It will be reasonably supposed, however, in accordance with the well-known variation of coefficient for standard orifices, that as the head is increased the coefficient of discharge for turbines would slightly decrease. Data to determine whether this is true or not are almost entirely wanting. It may be said, however, from inference by comparison with experiments on orifices under varying heads, that the coefficient of discharge probably differs slightly for turbines under high heads from that for similar wheels under lower heads, the rate of variation decreasing as the head increases.

The rating tables of manufacturers are deduced by making the discharge directly proportional to the square root of the head. This will be correct only in case the coefficient of discharge through the turbine orifices remains constant.

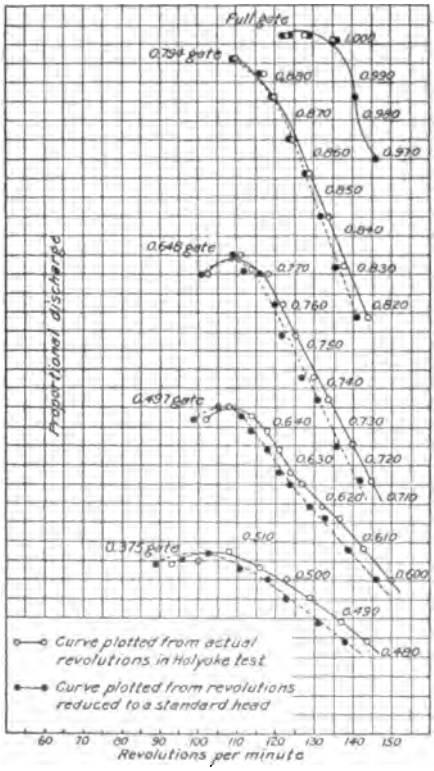


FIG. 31. Variation of turbine discharge with speed. 42-inch McCormick turbine.

Stock patterns of the turbines are seldom applied under heads exceeding 60 feet. The available records of tests of special high-head turbines in situ do not afford any means of determining what the discharge coefficient for the same turbines would be if they were operated under such heads as are commonly experienced with stock patterns of wheels.

## METHODS OF TURBINE SETTING AND ARRANGEMENT.

The rouet volante, scroll central-discharge, Fourneyron, and early Francis turbines were erected on vertical shafts in wooden or iron penstocks set alongside the flume to which they were connected by a short trunk or chute.

The tub wheel and the Jonval turbine were capable of being set over a hole in the bottom of an open flume. The greatly decreased cost of this mode of erection led to its general use in the latter half of the last century, and most turbines of the American type are designed with special reference to this mode of erection, several wheels often being set in the same flume. The serious disadvantage of this method is the impossibility of inspecting or repairing any wheel without stopping all and drawing off the water. For most purposes, except burrstone mills, power is required on horizontal shafts, and gears must be introduced if vertical turbines are used.

The step or thrust bearings of vertical turbines support the weight of the incumbent millwork and machinery. The weight and thrust of a vertical turbine is now often supported by a water-balanced step bearing, which relieves the mechanism of undue friction and wear. Where two wheels discharging in opposite directions are placed on a horizontal shaft the end thrust is neutralized (Pl. II). By inverting a vertical turbine and causing the water to flow upward through the buckets, the vertical component of pressure can be utilized for the same purpose, as it is in the Fourneyron turbines of the Niagara Falls Power Company's installation (fig. 3).

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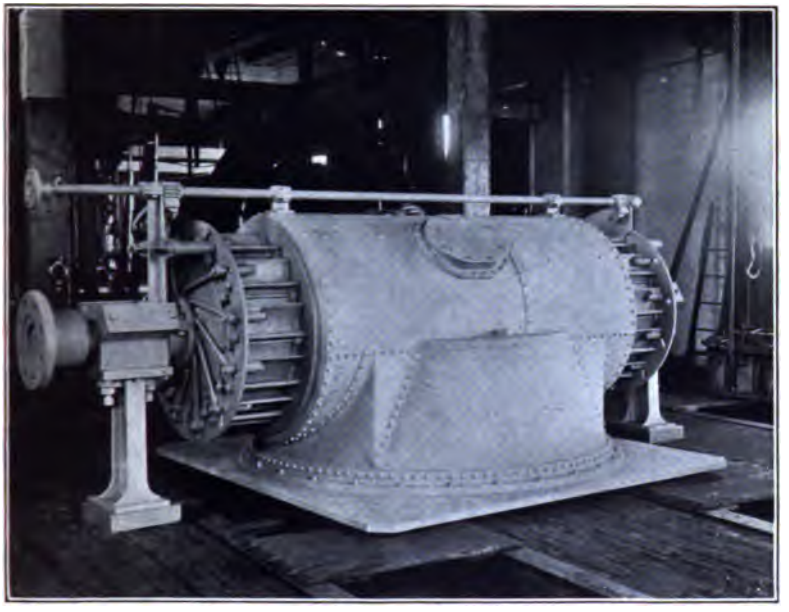
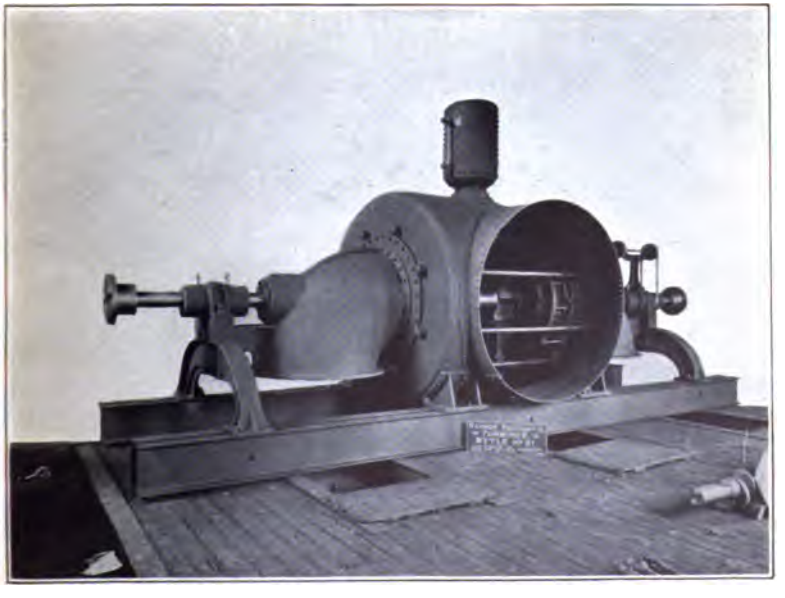


*A*. PAIR OF TURBINES WITH PIVOT GATES MOUNTED ON HORIZONTAL SHAFT AND DISCHARGING INTO A COMMON DRAFT TUBE.



*B*. PAIR OF TURBINES ON HORIZONTAL SHAFT.

Water is received from cylindrical steel penstock and discharged in opposite directions into quarter-turn draft tubes.

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Credit for the erection of the first pair of turbines on a horizontal shaft is claimed by E. Geyelin,[a] by whom the Jonval turbine was introduced into America about 1850. The draft tube was a feature of the Jonval turbine, and its use made the horizontal turbine possible, since without it a considerable portion of the head of horizontal wheels must be lost, as the wheels have to stand above tail-water.

Vertical turbines in open flumes must be set singly, one on a shaft. With the double horizontal arrangement power equal to that of a very large vertical turbine can be obtained together with a much greater speed.

Tests of turbines on horizontal shafts were made by James Emerson in 1879. A pair of 35-inch Gates-Curtis wheels with a rectangular wooden draft tube were used, and an average full-gate efficiency of 71.07 per cent was obtained, as compared with 82.52 per cent for one of the same runners tested vertically.

The result of this test and the belief that a horizontal wheel shaft would wear its bearings unequally and rub at the bottom and leak at the top of its case—a belief held by James Emerson—undoubtedly did much to delay the introduction of horizontal wheels. Their advantages are facility of access and facility of direct connection to generators, centrifugal pumps, and other machines, together with the ability to obtain large power on a single high-speed shaft, four or even six runners often being mounted tandem for this purpose.

Too much emphasis can not be laid upon the importance of allowing ample room all around the gate inlets where turbines are set in quarter-turn, globe, or cylindrical casings. The Holyoke Water Power Company gives the general rule: allow velocity in turbine casing not to exceed 3 feet per second and in draft tube not to exceed 4 or 5 feet per second.

The more common methods of turbine setting in power plants are as follows:

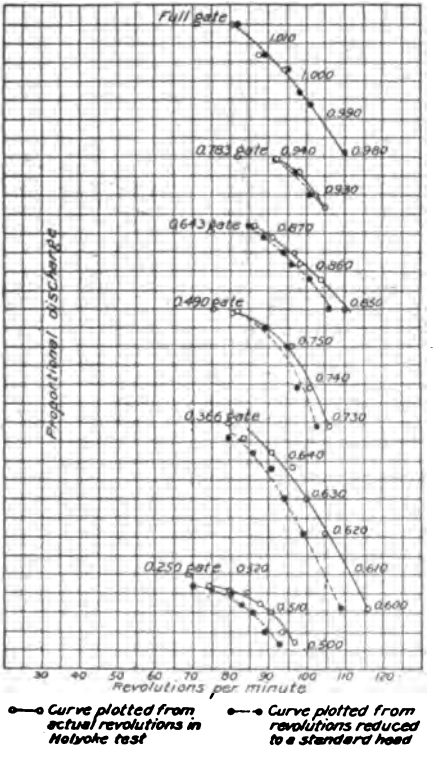


FIG. 32. Variation of turbine discharge with speed, 54-inch McCormick turbine.

1. Wheels may be arranged vertically in open flumes and connected by bevel gear harness. This method is well adapted for use under low heads. Several wheels can be controlled by one governor. Wheels can be arranged in units of three or four, which can be cut off successively by means of clutches beginning with the unit most remote from the driving end, thus allowing for variation of head and load. The governor may be attached to but one unit, additional units being controlled by hand and generally operated full gate, thus giving maximum efficiency for the system. Wheels are set in cast-iron penstocks or globe cases, or in cylindrical riveted steel penstocks in a number of ways. Single wheels are often placed in quarter-turn cases, with vertical or horizontal shafts. Double horizontal wheels may receive water from separate penstocks and discharge through a common draft tube, or may receive through a common penstock and have separate draft tubes; or they

[a] First pair of horizontal turbines ever built, working on a common axis: Proc. Eng. Club, Philadelphia, vol. 12, 1895, pp. 213–217.

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may have both feeder and draft tubes in common. The principal features of each method are included in the following classification.

2. Wheels may be arranged in pairs on a horizontal shaft, with a common draft tube. Each pair may be in a penstock compartment by itself, with drop planks at the entry, so that the water can be drawn from any pair without disturbing the others. This is an excellent and economical arrangement for moderate heads, say 12 to 40 feet, and one which gives large area and free access of water to wheel chutes from all sides. Two pairs in tandem, with quill shaft, can be used, enabling them to be operated singly or as a unit.

3. Horizontal pairs of runners may be set in a cylindrical steel penstock, having a common central-draft tube. This method is adapted to cases where a line of driving shaft can be placed parallel to a circular steel flume leading from the dam, or where several units are to be driven from a common bulkhead, in which case the wheels for each unit are in a short

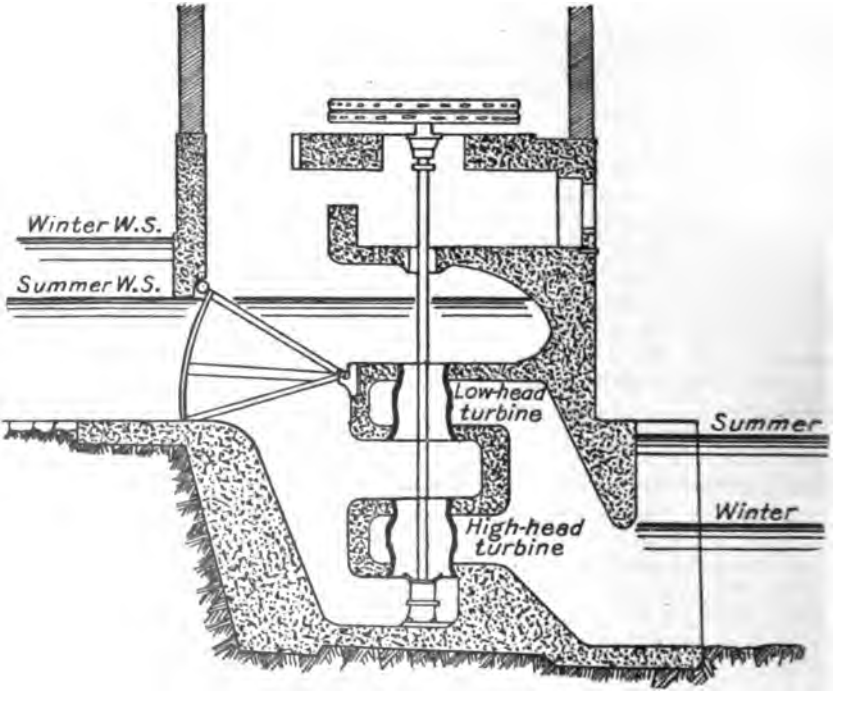


FIG. 33.—Cross section of power house, at Chevrés, near Geneva, Switzerland.

trunk leading from the foot of the bulkhead. A gate valve near the bulkhead will enable each unit to be separately cut off. Two wheel units, each containing either two, four, or even six pairs of runners, can be used in conjunction with a quill shaft, if desired.

4. Horizontal pairs of runners may be set in a cylindrical steel penstock, fed from the center and discharging outward into separate quarter-turn draft tubes. This arrangement possesses features similar to the preceding, but enables the driving shaft to be placed at right angles to the feeder trunk and also gives the water somewhat more freedom of access to wheel inlet ports. A feeder trunk is sometimes placed parallel to the power house, and short lateral feeders connect it with the penstocks, arranged as above. Short bends in the feeder line are, however, undesirable. This arrangement generally leaves a dead end at the foot of the penstock, in which ice may accumulate. A large blow-off valve should always be provided at the foot of a steel penstock.

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## TURBINE PLANTS FOR VARYING HEAD.

If the guide chutes of a turbine are designed with an area somewhat in excess of that required by theory at full gate, a wheel of very great capacity may be obtained, which will give its maximum efficiency at three-fourths or seven-eighths gate. (See figs. 14–19). Turbines for electrical service must nearly always have some reserve power and are seldom operated at full gate. With a fairly steady load, a moderate range of variation in the head may be taken care of with such wheels and uniform speed maintained by increasing the gate opening as the head decreases. Where there are large variations in the head, covering considerable periods of time, other expedients must be resorted to. The effect of a given range of variation in head increases rapidly as the head decreases. For example, the decrease in speed resulting from 1 foot decrease in head is as follows:

*Effect of varying heads on turbine speed.*

| Original head. | Decreased head. | Resulting speed (per cent of original). |
|---|---|---|
| *Feet.* | *Feet.* | |
| 4 | 3 | 86.60 |
| 10 | 9 | 94.87 |
| 50 | 49 | 99.00 |
| 100 | 99 | 99.50 |

In order to obtain uniform speed and power when operating under high head with small flow part of the time, and under a small head with large flow part of the time, two sets of turbines may be installed, one of large diameter, but with small openings, to operate under high head, the other of small effective diameter, but greater depth and capacity, for lower heads. Such an arrangement, in use at Chevrés, near Geneva, Switzerland, is illustrated in fig. 33. The upper wheel is used in winter with a head of 28 feet and a stream discharge of 4,250 cubic feet per second, and the lower wheel is used in summer with a head of 15 feet and a stream discharge of 31,800 cubic feet per second.

## CONDITIONS GOVERNING ECONOMY IN SIZE AND NUMBER OF TURBINES USED.

The cost of a turbine, including foundation and erection, is about proportional to its diameter. Small turbines are sometimes selected for use under low heads because of their greater speed, which enables them to be directly connected to machines. The writer observed in one case 26 small old register-gate turbines in one flume, doing only as much work as perhaps one-third their number of large modern wheels would have done, including loss through gearing and jack shaft.

*Turbines in use on Black River, New York, in 1898.*

| Diameter of wheel in inches. | Number. | Diameter of wheel in inches. | Number. |
|---|---|---|---|
| 18 to 27½ | 16 | 50 to 54 | 44 |
| 30 to 34 | 84 | 55 to 57 | 17 |
| 35 to 39 | 111 | 60 to 61 | 30 |
| 40 to 44 | 46 | 66 to 72 | 5 |
| 45 to 48 | 27 | | |
| | | Total.... | 380 |

In a canvass of water power on Black River, New York, in 1898, it was found that of a total of 380 turbines 50 per cent were from 30 to 40 inches diameter. In many places, notably at pulp mills, it was clearly evident that the use of larger turbines would have been more

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economical. The heads were those most commonly occurring everywhere—10 to 20 feet It was also found that 25 per cent of the wheels in use were operated at very uneconomica widths of gate opening, varying from one-fourth to three-fourths.

Turbines of medium sizes, of which the greater number are manufactured, are likely t be the most reliable and to give the best service. Manufacturers scales of prices are als so adjusted that turbines of medium sizes, 36 to 48 inches diameter, cost less per horsepowe than do sizes either larger or smaller.

The peripheral speed of maximum full-gate efficiency is, for turbines of a given design nearly a constant fraction of the spouting velocity due to the head. This is illustrated b the following tests of various sized Hercules turbines:

*Peripheral speed of Hercules turbines at full gate.*

| Diameter in inches. | Date of test. | Test number. | Head (in feet) at maximum efficiency. | $\sqrt{2gH}$= vel. due to head. | Speed in revolutions per minute. | Peripheral speed in feet per second. | Ratio: Col. 7. / Col. 5 |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 42..... | February 18-19, 1897... | 988 | 15.73 | 31.809 | 119.75 | 21.946 | 0.6899 |
| 45..... | July 19, 1897..... | 1030 | 15.75 | 31.829 | 111.20 | 21.804 | .6859 |
| 48..... | October 10-11, 1898.... | 1147 | 15.53 | 31.606 | 104.25 | 21.838 | .6908 |
| 51..... | February 25, 1898..... | 1077 | 14.01 | 30.020 | 91.25 | 20.306 | .6764 |
| 54..... | November 12, 1897 .... | 1051 | 14.07 | 30.084 | 84.12 | 19.820 | .6588 |

The discharge, and hence also the power of a turbine, is nearly proportional to the square of its diameter. The extent to which this is true in practice depends upon the similarity of form of different sized turbines of the same make. The members of certain series of patterns made by some builders are perfectly homologous, one particular size having been developed by experiments and others being made larger or smaller in strict proportion. For other types each size is a law unto itself, though, of course, there is a general resemblance between the different sizes. How nearly proportional to the square of the diameter is the discharge may be judged from the following table, in which the capacity of various sized Hercules and Smith No. 2 Success turbines are compared. The factor vent ÷ (Diam.$^2$) should be constant if the discharge is proportional to the square of the diameter. If the efficiency is constant, the power at a given head is proportional to the discharge.

*Relations between diameter and discharge and power of turbines of various sizes.*

| Diameter. | Square of diameter. | Hercules (cylinder gate). | | Smith No. 2 Success (pivot gate). | |
|---|---|---|---|---|---|
| | | Vent. | Vent / Diameter.$^2$ | Vent. | Vent / Diameter.$^2$ |
| *Inches.* | | *Sq. in.* | | *Sq. in.* | |
| 9 | 81 | 24.80 | 0.305 | ..... | ..... |
| 12 | 144 | 42.89 | .298 | ..... | ..... |
| 15 | 225 | 69.19 | .307 | 41 | 0.182 |
| 18 | 324 | 96.56 | .298 | 59 | .182 |
| 21 | 441 | 136 | .308 | 81 | .183 |
| 24 | 576 | 168 | .292 | 102 | .177 |
| 30 | 900 | 265 | .297 | 168 | .188 |
| 36 | 1,296 | 379 | .293 | 235 | .181 |
| 42 | 1,764 | 555 | .315 | 361 | .205 |
| 48 | 2,304 | 687 | .298 | 471 | .204 |
| 54 | 2,496 | 897 | .308 | 580 | .199 |
| 60 | 3,600 | 1,074 | .297 | 730 | .203 |

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It will be seen that for the Hercules and No. 2 Success the discharge as rated by the manufacturer is nearly proportional to the square of the diameter. Assuming the power to be proportional to the square of the diameter, the diameter D of a single turbine equal in power to two smaller wheels, each of diameter d, is:

$$D=\sqrt{2}\,d^2=1.41\,d.$$

If two equal wheels of diameter d are to replace a single wheel of diameter D, then

$$d=\frac{D}{\sqrt{2}}=\frac{1}{2}\sqrt{2}\times D=0.705\,D.$$

If m wheels each of diameter D are to replace n wheels of diameter d, then

$$mD^2=nd^2$$

and

$$D=d\sqrt{\frac{n}{m}}$$

$$d=D\sqrt{\frac{m}{n}}$$

If a single wheel of diameter D is to replace two wheels of unequal diameters $d_1$ and $d_2$, then

$$D=\sqrt{d_1^2+d_2^2}$$

Similarly, if m wheels of diameter D are to replace any series of wheels in which there are A wheels of diameter $d_a$, B wheels of diameter $d_b$, C wheels of diameter $d_c$, etc., then

$$mD^2=A\,d_a^2+B\,d_b^2+C\,d_c^2+\text{etc.}$$

or

$$D=\sqrt{\frac{1}{m}(A\,d_a^2+B\,d_b^2+C\,d_c^2+\text{etc.})}$$

Considerations like the above will be found convenient in selecting the best diameters and arrangements of turbines and in remodeling old plants.

## MANUFACTURER'S TABLES OF POWER, SPEED, AND DISCHARGE.

### GENERAL DISCUSSION.

Nearly all American turbine builders publish rating tables in their catalogues, showing the discharge in cubic feet per minute, speed in revolutions per minute, and horsepower for each size pattern under heads varying from 3 or 4 feet to 40 feet or more.

Inasmuch as these rating tables furnish in many cases the only means of ascertaining the quantities of water provided by riparian rights, or the amounts of power used by mills, the question of their reliability is of some importance.

Examples of each size of a number of the leading types of turbines have been tested in the Holyoke flume. For such turbines the rating tables have usually been prepared directly from the tests. In some cases the average of the full-gate power of a number of tests has been used; in other cases the power corresponding to maximum efficiency from a single test has been used as a basis for calculation.

Let M, R, and Q denote, respectively, the horsepower, revolutions per minute, and discharge in cubic feet per minute of a turbine, as expressed in the manufacturer's tables, for any head H in feet. The subscripts 1 and 16 added signify the power, speed, and discharge for the particular heads 1 and 16 feet, respectively.

Let P, N, and F denote coefficients of power, speed, and discharge, which represent, respectively, the horsepower, revolutions per minute, and discharge in cubic feet per second under a head of 1 foot.

The speed of a turbine or the number of revolutions per minute and the discharge are proportional to the square root of the head. The horsepower varies with the product of the head and discharge, and is consequently proportional to the three-halves power of the head.

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If we have given the values of M, R, and Q from the manufacturer's tables for any head H we can calculate these quantities for any other head h by the following formulas:

$$\left.\begin{aligned} M_H : M_h &:: H^{\frac{3}{2}} : h^{\frac{3}{2}} \\ R_H : R_h &:: H^{\frac{1}{2}} : h^{\frac{1}{2}} \\ Q_H : Q_h &:: H^{1} : h^{1} \end{aligned}\right\} \quad (1)$$

If H and h are taken at 16 feet and 1 foot, respectively, we may derive formulas from which the coefficients P, N, and F can be conveniently calculated as follows:

$$\left.\begin{aligned} P &= \frac{M_{16}}{H^{\frac{3}{2}}} = \frac{M_{16}}{64} = 0.01562\ M_{16} \\ N &= \frac{R_{16}}{H^{\frac{1}{2}}} = \frac{R_{16}}{4} = 0.25\ R_{16} \\ F &= \frac{Q_{16}}{60H^{\frac{1}{2}}} = \frac{Q_{16}}{240} = 0.00417\ Q_{16} \end{aligned}\right\} \quad (2)$$

P, N, and F, when derived for a given wheel, enable the power, speed, and dicharge to be calculated without the aid of the manufacturer's tables, and for any head H, integral or fractional, by means of the following formulas:

$$\left.\begin{aligned} M &= M_1 \left(\frac{H^{\frac{3}{2}}}{H_1}\right) = PH^{\frac{3}{2}} \\ R &= R_1 \sqrt{\frac{H}{H_1}} = N\sqrt{H} \\ Q &= Q_1 \sqrt{\frac{H}{H_1}} = 60\ F\sqrt{H} \end{aligned}\right\} \quad (3)$$

Since at a head of 1 foot, and $M_1$, $R_1$, and $Q_1$ equal P, N, and 60 F, respectively, $H_1^{\frac{3}{2}}$ and $\sqrt{H_1}$ each equals 1.

The accompanying tables give the values of P and N and F for turbines of various styles and sizes, and tables are appended giving three-halves powers and square roots, by the use of which the quantities can be calculated for any head and turbine with facility.

Besides presenting the individual constants of turbines in very compact form, as compared with manufacturer's rating tables, these coefficients afford a means for comparison of the capacity of different turbines.

The following examples illustrate the use of the tables:

On page 122 we find for a 36-inch Hercules turbine—

Power coefficient, 1.91 = P
Discharge coefficient, 21.1 = F
Speed coefficient, 32.2 = N

To find the power, discharge, and speed for any head, multiply P by the three-halves power of the head to get the horsepower, and mutiply F and N by the square root of the head to get the discharge in cubic feet per second and the revolutions per minute, respectively, or as formulas:

Horsepower = $PH^{\frac{3}{2}}$
Cubic feet per second = $FH^{\frac{1}{2}}$
Revolutions per minute = $NH^{\frac{1}{2}}$

To determine these factors for a head of, say, 7.5 feet, find in the tables of three-halves powers, and square roots, pages 90–94:

$7.5^{\frac{3}{2}} = 20.54$
$\sqrt{7.5} = 2.74$

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Multiplying, we get for a 36-inch Hercules turbine under 7.5 feet head—

Horsepower $=20.54\times 1.91=39.2$.
Cubic feet per second $=21.1\times 2.74=57.8$.
Revolutions per minute $=32.2\times 2.74=88.2$.

If the discharge in cubic feet per minute is desired, multiply the cubic feet per second by 60 and we get, cubic feet per minute=3,468.

Tests of different turbines from the same pattern have been found to agree closely if the conditions were similar. The manufacturers' rating tables can as a rule be relied upon within a small percentage, where they are obtained from complete test records as above described.

There are other turbines on the market for which tests of only one or two sizes of patterns have been made. In such cases, the rating tables for sizes other than those tested have been computed, usually on the following basis:

1. The efficiency and coefficients of gate and bucket discharge for the sizes tested have been assumed to apply to the other sizes also.
2. The discharge for additional sizes has been computed in proportion to the measured area of the vent or discharge orifices.

Having these data, together with the efficiency, the tables of discharge and horsepower can be prepared. The peripheral speed corresponding to maximum efficiency determined from tests of one size of turbine may be assumed to apply to the other sizes also. From this datum the revolutions per minute can be computed, the number of revolutions required to give a constant peripheral speed being inversely proportional to the diameter of the turbine.

Other turbines are on the market for which there appear to be no authentic tests of any sizes. Some of these wheels are close copies of known types, the rating tables for which have been adopted or slightly modified as seemed necessary.

In point of discharge, the writer's observation has been that the rating tables are usually fairly accurate. In the matter of efficiency there are undoubtedly much larger discrepancies.

The discharge of turbines is nearly always expressed in the manufacturers' tables in cubic feet per minute. The vent in square inches is also used by millwrights and manufacturers, although to a decreasing extent. Engineers prefer to express the discharge of turbines in cubic feet per second (second-feet) to conform with general practice in stream gaging and in power calculations. The vent of the turbines, as usually expressed, is the area of an orifice which would, under any given head, theoretically discharge the same quantity of water that is vented or passed through a turbine under that same head when the wheel is so loaded as to be running at maximum efficiency.

If V=vent in square inches
Q=discharge in cubic feet per minute under a head H
F=discharge in cubic feet per second under a head of 1 foot,

then

$$Q=\frac{60V}{144}\sqrt{2gH}=3.344V\sqrt{H}$$

and

$$V=\frac{144}{60}\frac{Q}{\sqrt{2gH}}=0.3\frac{Q}{\sqrt{H}}$$

also

$$V=17.94F \text{ and } F=0.0557V.$$

Manufacturers formerly gave the vent of their wheels in conjunction with the rating tables, and water privileges are often deeded in the terms of the right to use a certain number of "square inches" of water from a stream or power canal. As commonly interpreted, this implies no definite coefficient of contraction, the owner being entitled to use as much water as can flow naturally through an orifice of a given area, under the existing head. The limiting value of the coefficient of discharge is unity.

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In the use of scroll wheels, fed by short flumes leading out of the raceways, and having a contracted rectangular throat, the ventage agrees more or less closely with the area of the throat.

The vent of a turbine should not be confused with the area of the outlet orifice of the buckets. The actual discharge through a turbine is commonly from 40 to 60 per cent of the theoretical discharge of an orifice whose area equals the combined cross-sectional areas of the outlet ports measured in the narrowest section.

*Table of square roots for calculating discharge and speed of turbines.*

| Head in feet. | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0000 | 0.3162 | 0.4472 | 0.5477 | 0.6324 | 0.7071 | 0.7745 | 0.8366 | 0.8944 | 0.9486 |
| 1 | 1.0000 | 1.0488 | 1.0954 | 1.1401 | 1.1832 | 1.2247 | 1.2649 | 1.3038 | 1.3416 | 1.3784 |
| 2 | 1.4142 | 1.4491 | 1.4832 | 1.5165 | 1.5491 | 1.5811 | 1.6124 | 1.6431 | 1.6733 | 1.7291 |
| 3 | 1.7320 | 1.7606 | 1.7888 | 1.8165 | 1.8439 | 1.8708 | 1.8973 | 1.9235 | 1.9493 | 1.9748 |
| 4 | 2.0000 | 2.0248 | 2.0493 | 2.0736 | 2.0976 | 2.1213 | 2.1447 | 2.1679 | 2.1908 | 2.2135 |
| 5 | 2.2360 | 2.2583 | 2.2803 | 2.3021 | 2.3237 | 2.3452 | 2.3664 | 2.3874 | 2.4083 | 2.4289 |
| 6 | 2.4494 | 2.4698 | 2.4899 | 2.5099 | 2.5298 | 2.5495 | 2.5690 | 2.5884 | 2.6076 | 2.6267 |
| 7 | 2.6457 | 2.6645 | 2.6832 | 2.7018 | 2.7202 | 2.7386 | 2.7568 | 2.7748 | 2.7928 | 2.8106 |
| 8 | 2.8284 | 2.8460 | 2.8635 | 2.8809 | 2.8982 | 2.9154 | 2.9325 | 2.9495 | 2.9664 | 2.9832 |
| 9 | 3.0000 | 3.0166 | 3.0331 | 3.0495 | 3.0659 | 3.0822 | 3.0983 | 3.1144 | 3.1304 | 3.1464 |
| 10 | 3.1622 | 3.1780 | 3.1937 | 3.2093 | 3.2249 | 3.2403 | 3.2557 | 3.2710 | 3.2863 | 3.3015 |
| 11 | 3.3166 | 3.3316 | 3.3466 | 3.3615 | 3.3763 | 3.3911 | 3.4058 | 3.4205 | 3.4351 | 3.4496 |
| 12 | 3.4641 | 3.4785 | 3.4928 | 3.5071 | 3.5213 | 3.5355 | 3.5496 | 3.5637 | 3.5777 | 3.5916 |
| 13 | 3.6055 | 3.6193 | 3.6331 | 3.6469 | 3.6606 | 3.6742 | 3.6878 | 3.7013 | 3.7148 | 3.7282 |
| 14 | 3.7416 | 3.7549 | 3.7682 | 3.7815 | 3.7947 | 3.8078 | 3.8209 | 3.8340 | 3.8470 | 3.8600 |
| 15 | 3.8729 | 3.8858 | 3.8987 | 3.9115 | 3.9242 | 3.9370 | 3.9496 | 3.9623 | 3.9749 | 3.9874 |
| 16 | 4.0000 | 4.0124 | 4.0249 | 4.0373 | 4.0496 | 4.0620 | 4.0743 | 4.0865 | 4.0987 | 4.1109 |
| 17 | 4.1231 | 4.1352 | 4.1472 | 4.1593 | 4.1713 | 4.1833 | 4.1952 | 4.2071 | 4.2190 | 4.2308 |
| 18 | 4.2426 | 4.2544 | 4.2661 | 4.2778 | 4.2895 | 4.3011 | 4.3127 | 4.3243 | 4.3358 | 4.3474 |
| 19 | 4.3588 | 4.3703 | 4.3817 | 4.3931 | 4.4045 | 4.4158 | 4.4271 | 4.4384 | 4.4971 | 4.4609 |
| 20 | 4.4721 | 4.4833 | 4.4944 | 4.5055 | 4.5166 | 4.5276 | 4.5387 | 4.5497 | 4.5607 | 4.5716 |
| 21 | 4.5825 | 4.5934 | 4.6043 | 4.6151 | 4.6260 | 4.6368 | 4.6475 | 4.6583 | 4.6690 | 4.6797 |
| 22 | 4.6904 | 4.7010 | 4.7116 | 4.7222 | 4.7328 | 4.7434 | 4.7539 | 4.7644 | 4.7749 | 4.7853 |
| 23 | 4.7958 | 4.8062 | 4.8166 | 4.8270 | 4.8373 | 4.8476 | 4.8579 | 4.8682 | 4.8785 | 4.8887 |
| 24 | 4.8989 | 4.9091 | 4.9193 | 4.9295 | 4.9396 | 4.9497 | 4.9598 | 4.9699 | 4.9799 | 4.9899 |
| 25 | 5.0000 | 5.0099 | 5.0199 | 5.0299 | 5.0398 | 5.0497 | 5.0596 | 5.0695 | 5.0793 | 5.0892 |
| 26 | 5.0990 | 5.1088 | 5.1185 | 5.1283 | 5.1380 | 5.1478 | 5.1575 | 5.1672 | 5.1768 | 5.1865 |
| 27 | 5.1961 | 5.2057 | 5.2153 | 5.2249 | 5.2345 | 5.2440 | 5.2535 | 5.2630 | 5.2725 | 5.2820 |
| 28 | 5.2915 | 5.3009 | 5.3103 | 5.3197 | 5.3291 | 5.3385 | 5.3478 | 5.3572 | 5.3665 | 5.3758 |
| 29 | 5.3851 | 5.3944 | 5.4037 | 5.4129 | 5.4221 | 5.4313 | 5.4405 | 5.4977 | 5.4589 | 5.4680 |
| 30 | 5.4772 | 5.4863 | 5.4954 | 5.5045 | 5.5136 | 5.5226 | 5.5317 | 5.5407 | 5.5497 | 5.5587 |
| 31 | 5.5677 | 5.5767 | 5.5856 | 5.5946 | 5.6035 | 5.6124 | 5.6213 | 5.6302 | 5.6391 | 5.6480 |
| 32 | 5.6568 | 5.6656 | 5.6745 | 5.6833 | 5.6920 | 5.7008 | 5.7096 | 5.7183 | 5.7271 | 5.7358 |
| 33 | 5.7445 | 5.7532 | 5.7619 | 5.7706 | 5.7792 | 5.7879 | 5.7965 | 5.8051 | 5.8137 | 5.8223 |
| 34 | 5.8309 | 5.8395 | 5.8480 | 5.8566 | 5.8651 | 5.8736 | 5.8821 | 5.8906 | 5.8991 | 5.9076 |
| 35 | 5.9160 | 5.9245 | 5.9329 | 5.9413 | 5.9497 | 5.9581 | 5.9665 | 5.9749 | 5.9833 | 5.9916 |
| 36 | 6.0000 | 6.0083 | 6.0166 | 6.0249 | 6.0332 | 6.0415 | 6.0497 | 6.0580 | 6.0663 | 6.0745 |
| 37 | 6.0827 | 6.0909 | 6.0991 | 6.1073 | 6.1155 | 6.1237 | 6.1318 | 6.1400 | 6.1481 | 6.1562 |
| 38 | 6.1644 | 6.1725 | 6.1806 | 6.1886 | 6.1967 | 6.2048 | 6.2128 | 6.2209 | 6.2289 | 6.2369 |
| 39 | 6.2449 | 6.2529 | 6.2609 | 6.2689 | 6.2769 | 6.2849 | 6.2928 | 6.3007 | 6.3087 | 6.3166 |
| 40 | 6.3245 | 6.3324 | 6.3403 | 6.3482 | 6.3560 | 6.3639 | 6.3718 | 6.3796 | 6.3874 | 6.3953 |

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*Table of square roots for calculating discharge and speed of turbines*—Continued.

| Head in feet. | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 6.4031 | 6.4109 | 6.4187 | 6.4265 | 6.4342 | 6.4420 | 6.4498 | 6.4575 | 6.4652 | 6.4730 |
| 42 | 6.4807 | 6.4884 | 6.4961 | 6.5038 | 6.5115 | 6.5192 | 6.5268 | 6.5345 | 6.5421 | 6.5498 |
| 43 | 6.5574 | 6.5650 | 6.5726 | 6.5802 | 6.5878 | 6.5954 | 6.6030 | 6.6105 | 6.6181 | 6.6257 |
| 44 | 6.6332 | 6.6407 | 6.6483 | 6.6558 | 6.6633 | 6.6708 | 6.6783 | 6.6858 | 6.6932 | 6.7007 |
| 45 | 6.7082 | 6.7156 | 6.7230 | 6.7305 | 6.7379 | 6.7453 | 6.7527 | 6.7601 | 6.7675 | 6.7749 |
| 46 | 6.7823 | 6.7896 | 6.7970 | 6.8044 | 6.8117 | 6.8190 | 6.8264 | 6.8337 | 6.8410 | 6.8483 |
| 47 | 6.8556 | 6.8629 | 6.8702 | 6.8774 | 6.8847 | 6.8920 | 6.8992 | 6.9065 | 6.9137 | 6.9209 |
| 48 | 6.9282 | 6.9354 | 6.9426 | 6.9498 | 6.9570 | 6.9641 | 6.9713 | 6.9785 | 6.9856 | 6.9928 |
| 49 | 7.0000 | 7.0071 | 7.0142 | 7.0213 | 7.0285 | 7.0356 | 7.0427 | 7.0498 | 7.0569 | 7.0639 |
| 50 | 7.0710 | 7.0781 | 7.0851 | 7.0922 | 7.0992 | 7.1063 | 7.1133 | 7.1203 | 7.1274 | 7.1344 |
| 51 | 7.1414 | 7.1484 | 7.1554 | 7.1624 | 7.1693 | 7.1763 | 7.1833 | 7.1902 | 7.1972 | 7.2041 |
| 52 | 7.2111 | 7.2180 | 7.2249 | 7.2318 | 7.2387 | 7.2456 | 7.2525 | 7.2594 | 7.2663 | 7.2732 |
| 53 | 7.2801 | 7.2869 | 7.2938 | 7.3006 | 7.3075 | 7.3143 | 7.3212 | 7.3280 | 7.3348 | 7.3416 |
| 54 | 7.3484 | 7.3552 | 7.3620 | 7.3688 | 7.3756 | 7.3824 | 7.3891 | 7.3959 | 7.4027 | 7.4094 |
| 55 | 7.4161 | 7.4229 | 7.4296 | 7.4363 | 7.4431 | 7.4498 | 7.4565 | 7.4632 | 7.4699 | 7.4766 |
| 56 | 7.4833 | 7.4899 | 7.4966 | 7.5033 | 7.5099 | 7.5166 | 7.5232 | 7.5299 | 7.5365 | 7.5432 |
| 57 | 7.5498 | 7.5564 | 7.5630 | 7.5696 | 7.5762 | 7.5828 | 7.5894 | 7.5960 | 7.6026 | 7.6092 |
| 58 | 7.6157 | 7.6223 | 7.6288 | 7.6354 | 7.6419 | 7.6485 | 7.6550 | 7.6615 | 7.6681 | 7.6746 |
| 59 | 7.6811 | 7.6876 | 7.6941 | 7.7006 | 7.7071 | 7.7136 | 7.7201 | 7.7265 | 7.7330 | 7.7395 |
| 60 | 7.7459 | 7.7524 | 7.7588 | 7.7653 | 7.7717 | 7.7781 | 7.7846 | 7.7910 | 7.7974 | 7.8038 |
| 61 | 7.8102 | 7.8166 | 7.8230 | 7.8294 | 7.8358 | 7.8421 | 7.8485 | 7.8549 | 7.8612 | 7.8676 |
| 62 | 7.8740 | 7.8803 | 7.8866 | 7.8930 | 7.8993 | 7.9056 | 7.9120 | 7.9183 | 7.9246 | 7.9309 |
| 63 | 7.9372 | 7.9435 | 7.9498 | 7.9561 | 7.9624 | 7.9686 | 7.9749 | 7.9812 | 7.9874 | 7.9937 |
| 64 | 8.0000 | 8.0062 | 8.0124 | 8.0187 | 8.0249 | 8.0311 | 8.0374 | 8.0436 | 8.0498 | 8.0560 |
| 65 | 8.0622 | 8.0684 | 8.0746 | 8.0808 | 8.0870 | 8.0932 | 8.0993 | 8.1055 | 8.1117 | 8.1178 |
| 66 | 8.1240 | 8.1301 | 8.1363 | 8.1424 | 8.1486 | 8.1547 | 8.1608 | 8.1670 | 8.1731 | 8.1792 |
| 67 | 8.1853 | 8.1914 | 8.1975 | 8.2036 | 8.2097 | 8.2158 | 8.2192 | 8.2280 | 8.2340 | 8.2401 |
| 68 | 8.2462 | 8.2522 | 8.2583 | 8.2643 | 8.2704 | 8.2764 | 8.2825 | 8.2885 | 8.2945 | 8.3006 |
| 69 | 8.3066 | 8.3126 | 8.3186 | 8.3246 | 8.3306 | 8.3366 | 8.3426 | 8.3486 | 8.3546 | 8.3606 |
| 70 | 8.3666 | 8.3725 | 8.3785 | 8.3845 | 8.3904 | 8.3964 | 8.4023 | 8.4083 | 8.4142 | 8.4202 |
| 71 | 8.4261 | 8.4320 | 8.4380 | 8.4439 | 8.4498 | 8.4557 | 8.4616 | 8.4675 | 8.4734 | 8.4793 |
| 72 | 8.4852 | 8.4911 | 8.4970 | 8.5029 | 8.5088 | 8.5146 | 8.5205 | 8.5264 | 8.5322 | 8.5381 |
| 73 | 8.5440 | 8.5498 | 8.5556 | 8.5615 | 8.5673 | 8.5732 | 8.5790 | 8.5848 | 8.5906 | 8.5965 |
| 74 | 8.6023 | 8.6081 | 8.6139 | 8.6197 | 8.6255 | 8.6313 | 8.6371 | 8.6429 | 8.6486 | 8.6544 |
| 75 | 8.6602 | 8.6662 | 8.6717 | 8.6775 | 8.6833 | 8.6890 | 8.6948 | 8.7005 | 8.7063 | 8.7120 |
| 76 | 8.7177 | 8.7235 | 8.7292 | 8.7349 | 8.7407 | 8.7464 | 8.7521 | 8.7578 | 8.7635 | 8.7692 |
| 77 | 8.7749 | 8.7806 | 8.7863 | 8.7920 | 8.7977 | 8.8034 | 8.8090 | 8.8147 | 8.8204 | 8.8260 |
| 78 | 8.8317 | 8.8374 | 8.8430 | 8.8487 | 8.8543 | 8.8600 | 8.8656 | 8.8713 | 8.8769 | 8.8825 |
| 79 | 8.8881 | 8.8938 | 8.8994 | 8.9050 | 8.9106 | 8.9162 | 8.9218 | 8.9274 | 8.9330 | 8.9386 |
| 80 | 8.9442 | 8.9498 | 8.9554 | 8.9610 | 8.9666 | 8.9721 | 8.9777 | 8.9833 | 8.9888 | 8.9944 |
| 81 | 9.0000 | 9.0055 | 9.0111 | 9.0166 | 9.0221 | 9.0277 | 9.0332 | 9.0388 | 9.0443 | 9.0498 |
| 82 | 9.0553 | 9.0609 | 9.0664 | 9.0719 | 9.0774 | 9.0829 | 9.0884 | 9.0939 | 9.0994 | 9.1049 |
| 83 | 9.1104 | 9.1159 | 9.1214 | 9.1268 | 9.1323 | 9.1378 | 9.1433 | 9.1487 | 9.1542 | 9.1596 |
| 84 | 9.1651 | 9.1706 | 9.1760 | 9.1815 | 9.1869 | 9.1923 | 9.1978 | 9.2032 | 9.2086 | 9.2141 |
| 85 | 9.2195 | 9.2249 | 9.2303 | 9.2357 | 9.2412 | 9.2466 | 9.2520 | 9.2574 | 9.2628 | 9.2682 |
| 86 | 9.2736 | 9.2790 | 9.2843 | 9.2897 | 9.2951 | 9.3005 | 9.3059 | 9.3112 | 9.3166 | 9.3220 |
| 87 | 9.3273 | 9.3327 | 9.3380 | 9.3434 | 9.3487 | 9.3541 | 9.3594 | 9.3648 | 9.3701 | 9.3754 |
| 88 | 9.3808 | 9.3861 | 9.3914 | 9.3968 | 9.4021 | 9.4074 | 9.4127 | 9.4180 | 9.4233 | 9.4286 |
| 89 | 9.4339 | 9.4392 | 9.4445 | 9.4498 | 9.4551 | 9.4604 | 9.4657 | 9.4710 | 9.4762 | 9.4815 |
| 90 | 9.4868 | 9.4921 | 9.4973 | 9.5026 | 9.5078 | 9.5131 | 9.5184 | 9.5236 | 9.5289 | 9.5341 |

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*Table of square roots for calculating discharge and speed of turbines*—Continued.

| Head in feet. | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 91 | 9.5393 | 9.5446 | 9.5498 | 9.5551 | 9.5603 | 9.5655 | 9.5707 | 9.5760 | 9.5812 | 9.5864 |
| 92 | 9.5916 | 9.5968 | 9.6020 | 9.6072 | 9.6124 | 9.6176 | 9.6228 | 9.6280 | 9.6332 | 9.6384 |
| 93 | 9.6436 | 9.6488 | 9.6540 | 9.6591 | 9.6643 | 9.6695 | 9.6747 | 9.6798 | 9.6850 | 9.6902 |
| 94 | 9.6953 | 9.7005 | 9.7056 | 9.7108 | 9.7159 | 9.7211 | 9.7262 | 9.7313 | 9.7365 | 9.7416 |
| 95 | 9.7467 | 9.7519 | 9.7570 | 9.7621 | 9.7672 | 9.7724 | 9.7775 | 9.7826 | 9.7877 | 9.7928 |
| 96 | 9.7979 | 9.8030 | 9.8081 | 9.8132 | 9.8183 | 9.8234 | 9.8285 | 9.8336 | 9.8386 | 9.8437 |
| 97 | 9.8488 | 9.8539 | 9.8590 | 9.8640 | 9.8691 | 9.8742 | 9.8792 | 9.8843 | 9.8893 | 9.8944 |
| 98 | 9.8994 | 9.9045 | 9.9095 | 9.9146 | 9.9196 | 9.9247 | 9.9297 | 9.9347 | 9.9398 | 9.9448 |
| 99 | 9.9498 | 9.9548 | 9.9599 | 9.9649 | 9.9699 | 9.9749 | 9.9799 | 9.9849 | 9.9899 | 9.9949 |
| 100 | | | | | | | | | | |

*Table of $H^{\frac{3}{2}}$ for calculating horsepower of turbines.*[a]

| Head in feet. | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0000 | 0.0316 | 0.0894 | 0.1643 | 0.2530 | 0.3536 | 0.4648 | 0.5857 | 0.7155 | 0.8538 |
| 1 | 1.0000 | 1.1537 | 1.3145 | 1.4822 | 1.6565 | 1.8371 | 2.0238 | 2.2165 | 2.4150 | 2.6190 |
| 2 | 2.8284 | 3.0432 | 3.2631 | 3.4881 | 3.7181 | 3.9529 | 4.1924 | 4.4366 | 4.6853 | 4.9385 |
| 3 | 5.1962 | 5.4581 | 5.7243 | 5.9947 | 6.2693 | 6.5479 | 6.8305 | 7.1171 | 7.4076 | 7.7019 |
| 4 | 8.0000 | 8.3019 | 8.6074 | 8.9167 | 9.2295 | 9.5459 | 9.8659 | 10.1894 | 10.5163 | 10.8466 |
| 5 | 11.1803 | 11.5174 | 11.8578 | 12.2015 | 12.5485 | 12.8986 | 13.2520 | 13.6086 | 13.9682 | 14.3311 |
| 6 | 14.6969 | 15.0659 | 15.4379 | 15.8129 | 16.1909 | 16.5718 | 16.9557 | 17.3425 | 17.7322 | 18.1248 |
| 7 | 18.5203 | 18.9185 | 19.3196 | 19.7235 | 20.1302 | 20.5396 | 20.9518 | 21.3666 | 21.7842 | 22.2045 |
| 8 | 22.6274 | 23.0530 | 23.4812 | 23.9121 | 24.3455 | 24.7815 | 25.2202 | 25.6613 | 26.1050 | 26.5513 |
| 9 | 27.0000 | 27.4512 | 27.9050 | 28.3612 | 28.8199 | 29.2810 | 29.7445 | 30.2105 | 30.6789 | 31.1496 |
| 10 | 31.6228 | 32.0983 | 32.5762 | 33.0564 | 33.5390 | 34.0239 | 34.5111 | 35.0006 | 35.4924 | 35.9865 |
| 11 | 36.4829 | 36.9815 | 37.4824 | 37.9855 | 38.4908 | 38.9984 | 39.5082 | 40.0202 | 40.5343 | 41.0507 |
| 12 | 41.5692 | 42.0910 | 42.6128 | 43.1388 | 43.6648 | 44.1952 | 44.7256 | 45.2600 | 45.7944 | 46.3332 |
| 13 | 46.8720 | 47.4148 | 47.9576 | 48.5048 | 49.0520 | 49.6032 | 50.1544 | 50.7096 | 51.2648 | 51.8240 |
| 14 | 52.3832 | 52.9464 | 53.5096 | 54.0768 | 54.6440 | 55.2152 | 55.7864 | 56.3616 | 56.9368 | 57.5156 |
| 15 | 58.0944 | 58.6776 | 59.2608 | 59.8472 | 60.4336 | 61.0244 | 61.6152 | 62.2096 | 62.8040 | 63.4020 |
| 16 | 64.0000 | 64.6020 | 65.2040 | 65.8096 | 66.4152 | 67.0244 | 67.6336 | 68.2464 | 68.8592 | 69.4760 |
| 17 | 70.0928 | 70.7132 | 71.3336 | 71.9572 | 75.5808 | 73.2084 | 73.8360 | 74.4672 | 75.0984 | 75.7328 |
| 18 | 76.3672 | 77.0056 | 77.6440 | 78.2856 | 78.9272 | 79.5724 | 80.2176 | 80.8664 | 81.5152 | 82.1672 |
| 19 | 82.8192 | 83.4748 | 84.1304 | 84.7892 | 85.4480 | 86.1104 | 86.7728 | 87.4384 | 88.1040 | 88.7732 |
| 20 | 89.4424 | 90.1152 | 90.7880 | 91.4636 | 92.1392 | 92.8184 | 93.4976 | 94.1800 | 94.8624 | 95.5484 |
| 21 | 96.2344 | 96.9232 | 97.6120 | 98.3044 | 98.9968 | 99.6924 | 100.3880 | 101.0868 | 101.7856 | 102.4872 |
| 22 | 103.1888 | 103.8940 | 104.6008 | 105.3076 | 106.0160 | 106.7276 | 107.4392 | 108.1540 | 108.8688 | 109.5864 |
| 23 | 110.3040 | 111.0248 | 111.7456 | 112.4700 | 113.1944 | 113.9216 | 114.6488 | 115.3788 | 116.1088 | 116.8420 |
| 24 | 117.5752 | 118.3128 | 119.0496 | 119.7876 | 120.5272 | 121.2696 | 122.0120 | 122.7576 | 123.5032 | 124.2516 |
| 25 | 125.0000 | 125.7516 | 126.5032 | 127.2576 | 128.0120 | 128.7706 | 129.5292 | 130.2876 | 131.0480 | 131.8112 |
| 26 | 132.5744 | 133.3408 | 134.1072 | 134.8764 | 135.6456 | 136.4180 | 137.1904 | 137.9652 | 138.7400 | 139.5180 |
| 27 | 140.2960 | 141.0768 | 141.8576 | 142.6416 | 143.4256 | 144.2120 | 144.9984 | 145.7880 | 146.5776 | 147.3700 |
| 28 | 148.1624 | 148.9572 | 149.7520 | 150.5500 | 151.3480 | 152.1488 | 152.9496 | 153.7532 | 154.5568 | 155.3632 |
| 29 | 156.1696 | 156.9788 | 157.7880 | 158.6000 | 159.4120 | 160.2268 | 161.0416 | 161.8588 | 162.6760 | 163.4964 |
| 30 | 164.3168 | 165.1396 | 165.9624 | 166.7884 | 167.6144 | 168.4428 | 169.2712 | 170.1020 | 170.9328 | 171.7668 |

[a] Original.

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*Table of $H^{\frac{3}{2}}$ for calculating horsepower of turbines*—Continued.[a]

| Head in feet. | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 172.6008 | 173.4372 | 174.2736 | 175.1128 | 175.9520 | 176.7940 | 177.6360 | 178.4804 | 179.3248 | 180.1720 |
| 32 | 181.0192 | 181.8692 | 182.7192 | 183.5716 | 184.4240 | 185.2792 | 186.1344 | 186.9920 | 187.8496 | 188.7100 |
| 33 | 189.5704 | 190.4336 | 191.2968 | 192.1624 | 193.0280 | 193.8960 | 194.7640 | 195.6348 | 196.5056 | 197.3788 |
| 34 | 198.2520 | 199.1460 | 200.0400 | 200.9008 | 201.7616 | 202.6424 | 203.5232 | 204.4068 | 205.2904 | 206.1764 |
| 35 | 207.0624 | 207.9512 | 208.8400 | 209.7312 | 210.6224 | 211.5204 | 212.4184 | 213.3104 | 214.2024 | 215.1012 |
| 36 | 216.0000 | 216.9012 | 217.8024 | 218.7060 | 219.6096 | 220.5760 | 221.4224 | 222.3312 | 223.2400 | 224.1512 |
| 37 | 225.0624 | 225.9760 | 226.8896 | 227.8056 | 228.7216 | 299.6404 | 230.5592 | 231.4800 | 232.4008 | 233.3244 |
| 38 | 234.2480 | 235.1736 | 236.0992 | 237.0276 | 237.9560 | 238.8868 | 239.8176 | 240.7508 | 241.6840 | 242.6196 |
| 39 | 243.5552 | 244.4932 | 245.4312 | 246.3712 | 247.3112 | 248.2540 | 249.1968 | 250.1420 | 251.0872 | 252.0348 |
| 40 | 252.9824 | 253.9320 | 254.8816 | 255.8340 | 256.7864 | 257.7412 | 258.6960 | 259.6528 | 260.6096 | 261.5688 |
| 41 | 262.5280 | 263.4896 | 264.4512 | 265.4152 | 266.3792 | 267.3456 | 268.3120 | 269.2804 | 270.2488 | 271.2200 |
| 42 | 272.1912 | 273.1644 | 274.1376 | 275.1132 | 276.0888 | 277.0672 | 278.0456 | 279.6252 | 280.0048 | 280.9872 |
| 43 | 281.9696 | 282.9544 | 283.9392 | 284.9264 | 285.9136 | 286.9028 | 287.8920 | 288.8836 | 289.8752 | 290.8692 |
| 44 | 291.8632 | 292.8597 | 293.8552 | 294.8536 | 295.8520 | 296.8528 | 297.8536 | 298.8564 | 299.8592 | 300.8640 |
| 45 | 301.8688 | 302.8764 | 303.8840 | 304.8936 | 305.9032 | 306.9148 | 307.9264 | 308.9404 | 309.9544 | 310.9708 |
| 46 | 311.9872 | 313.0056 | 314.0240 | 315.0448 | 316.0656 | 317.0877 | 318.1112 | 319.0556 | 320.0000 | 321.1080 |
| 47 | 322.2160 | 323.2452 | 324.2744 | 325.3060 | 326.3376 | 327.3716 | 328.4056 | 329.4416 | 330.4776 | 331.5156 |
| 48 | 332.5536 | 333.5927 | 334.6333 | 335.4753 | 336.7188 | 337.7588 | 338.8051 | 339.8529 | 340.8972 | 341.9479 |
| 49 | 343.0000 | 344.0486 | 345.0986 | 346.1500 | 347.2079 | 348.2622 | 349.3179 | 350.3750 | 351.4336 | 352.4886 |
| 50 | 353.5500 | 354.6128 | 355.6720 | 356.7376 | 357.7996 | 358.8681 | 359.9329 | 360.9992 | 362.0719 | 363.1409 |
| 51 | 364.2114 | 365.2832 | 366.3564 | 367.4311 | 368.5020 | 369.5794 | 370.6582 | 371.7333 | 372.8149 | 373.8927 |
| 52 | 374.9772 | 376.0578 | 377.1397 | 378.2331 | 379.3078 | 380.3940 | 381.4815 | 382.5703 | 383.6606 | 384.7522 |
| 53 | 385.8453 | 386.9343 | 388.0301 | 389.1219 | 390.2205 | 391.3150 | 392.4163 | 393.5136 | 394.6122 | 395.7122 |
| 54 | 396.8136 | 397.9163 | 399.0204 | 400.1258 | 401.2326 | 402.3408 | 403.4448 | 404.5557 | 405.6679 | 406.7759 |
| 55 | 407.8855 | 409.0017 | 410.1139 | 411.2273 | 412.3477 | 413.4639 | 414.5814 | 415.7002 | 416.8204 | 417.9419 |
| 56 | 419.0648 | 420.1833 | 421.3089 | 422.4257 | 423.5583 | 424.6879 | 425.8131 | 426.9453 | 428.0732 | 429.2080 |
| 57 | 430.3386 | 431.4704 | 432.6036 | 433.7380 | 434.8738 | 436.0110 | 437.1494 | 438.2892 | 439.4302 | 440.5726 |
| 58 | 441.7106 | 442.8556 | 443.9961 | 445.1438 | 446.2869 | 447.4372 | 448.5830 | 449.7300 | 450.8842 | 452.0359 |
| 59 | 454.0849 | 455.3271 | 455.4907 | 456.6455 | 457.8017 | 458.9592 | 460.1179 | 461.2720 | 462.4334 | 463.5960 |
| 60 | 464.7540 | 465.9192 | 467.0797 | 468.2475 | 469.4106 | 470.5750 | 471.7467 | 472.9137 | 474.0819 | 475.2514 |
| 61 | 476.4222 | 477.3942 | 478.7676 | 479.9422 | 481.1181 | 482.2891 | 483.4676 | 484.6473 | 485.8222 | 487.0044 |
| 62 | 488.1880 | 489.3666 | 490.5465 | 491.7339 | 492.9163 | 494.1000 | 495.2912 | 496.4774 | 497.6648 | 498.8536 |
| 63 | 500.0436 | 501.2348 | 502.4273 | 503.6211 | 504.8161 | 506.0061 | 507.2036 | 508.4024 | 509.5961 | 510.7974 |
| 64 | 512.0000 | 513.1974 | 514.3960 | 515.6024 | 516.8035 | 518.0059 | 519.2160 | 520.4209 | 521.6270 | 522.8344 |
| 65 | 524.0430 | 525.2528 | 526.4639 | 527.6762 | 528.8898 | 530.1046 | 531.3120 | 532.5313 | 533.7498 | 534.9630 |
| 66 | 536.1840 | 537.2996 | 538.6230 | 539.8411 | 541.0670 | 542.2875 | 543.5092 | 544.7389 | 545.9630 | 547.1884 |
| 67 | 548.4151 | 549.6429 | 550.8720 | 552.1022 | 553.3337 | 554.5665 | 555.6179 | 557.0356 | 558.2652 | 559.5027 |
| 68 | 560.7416 | 561.9748 | 563.2160 | 564.4516 | 565.6953 | 566.9334 | 568.1795 | 569.4199 | 570.6616 | 571.9113 |
| 69 | 573.1554 | 574.4006 | 575.6473 | 576.8947 | 578.1436 | 579.3937 | 580.6449 | 581.8974 | 583.1510 | 584.4059 |
| 70 | 585.6620 | 586.9122 | 588.1707 | 589.4303 | 590.6841 | 591.9462 | 593.2023 | 594.4668 | 595.7253 | 596.9921 |
| 71 | 598.2531 | 599.5152 | 600.7856 | 602.0500 | 603.3157 | 604.5825 | 605.8505 | 607.1197 | 608.3901 | 609.6616 |
| 72 | 610.9344 | 612.2083 | 613.4340 | 614.7596 | 616.0371 | 617.3085 | 618.5883 | 619.8692 | 621.0841 | 622.4274 |
| 73 | 623.7120 | 624.9903 | 626.2699 | 627.5579 | 628.8398 | 630.1302 | 631.4144 | 632.6997 | 633.9862 | 635.2813 |
| 74 | 636.5702 | 637.8602 | 639.1513 | 640.4437 | 641.7372 | 643.0318 | 644.3276 | 645.6246 | 646.9152 | 648.2145 |
| 75 | 649.5150 | 650.8166 | 652.1118 | 653.4157 | 654.7208 | 656.0195 | 657.3268 | 658.6278 | 659.9375 | 661.2408 |
| 76 | 662.5452 | 663.8583 | 665.1650 | 666.4728 | 667.7894 | 669.0996 | 670.4108 | 671.7131 | 673.0368 | 674.3514 |
| 77 | 675.6673 | 676.9842 | 677.2043 | 679.6216 | 680.9419 | 682.2635 | 683.5784 | 684.9021 | 686.2271 | 687.5454 |
| 78 | 688.8726 | 690.2009 | 691.5226 | 692.8532 | 694.1771 | 695.5100 | 696.8361 | 698.1713 | 699.4997 | 700.8292 |
| 79 | 702.1599 | 703.4995 | 704.8324 | 706.1665 | 707.5016 | 708.8379 | 710.1752 | 711.5137 | 712.8534 | 714.1941 |
| 80 | 715.5360 | 716.8789 | 718.2230 | 719.5683 | 720.9146 | 722.2540 | 723.6026 | 724.9523 | 726.2950 | 727.6498 |

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*Table of $H^{\frac{3}{2}}$ for calculating horsepower of turbines*—Continued.

| Head in feet. | 0.0. | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 81..... | 729.0000 | 730.3460 | 731.7613 | 733.0495 | 734.3989 | 735.7575 | 737.1091 | 738.4699 | 739.8237 | 741.1876 |
| 82..... | 742.5346 | 743.8998 | 745.2580 | 746.6173 | 747.9776 | 749.3392 | 750.7018 | 752.0655 | 753.4303 | 754.7962 |
| 83..... | 756.1632 | 757.5312 | 758.9004 | 760.2624 | 761.6338 | 763.0063 | 764.3798 | 765.7461 | 767.1219 | 768.4904 |
| 84..... | 769.8684 | 771.2474 | 772.6192 | 774.0004 | 775.3743 | 776.7493 | 778.1338 | 779.5110 | 780.8992 | 782.2770 |
| 85..... | 783.6575 | 785.0389 | 786.4215 | 787.8052 | 789.1984 | 790.5843 | 791.9712 | 793.3591 | 794.7482 | 796.1383 |
| 86..... | 797.5296 | 798.9219 | 800.3066 | 801.7011 | 803.0966 | 804.4932 | 805.8909 | 807.2810 | 808.6808 | 810.0833 |
| 87..... | 811.4751 | 812.8781 | 814.2736 | 815.6788 | 817.0763 | 818.4837 | 819.8834 | 821.2929 | 822.6947 | 824.1064 |
| 88..... | 825.5704 | 826.9154 | 828.3214 | 829.7374 | 831.1456 | 832.5549 | 833.9652 | 835.3766 | 836.7890 | 838.2025 |
| 89..... | 839.6171 | 841.0327 | 842.4494 | 843.8671 | 845.2859 | 846.7058 | 848.1267 | 849.5487 | 850.9627 | 852.3868 |
| 90..... | 853.8120 | 855.2382 | 856.6564 | 858.0847 | 859.5051 | 860.9355 | 862.3670 | 863.7905 | 865.2241 | 866.6496 |
| 91..... | 868.0763 | 869.5130 | 870.9417 | 872.3806 | 873.8114 | 875.2432 | 876.6761 | 878.1192 | 879.5541 | 880.9901 |
| 92..... | 882.4272 | 883.8652 | 885.3044 | 886.7445 | 888.1857 | 889.6280 | 891.0712 | 892.5156 | 893.9609 | 895.4073 |
| 93..... | 896.8548 | 898.3032 | 899.7528 | 901.1946 | 902.6456 | 904.0982 | 905.5519 | 906.9972 | 908.4530 | 909.9097 |
| 94..... | 911.3582 | 912.8170 | 914.2675 | 915.7284 | 917.1809 | 918.6439 | 920.0985 | 921.5541 | 923.0202 | 924.4778 |
| 95..... | 925.9365 | 927.4056 | 928.8664 | 930.3281 | 931.7908 | 933.2642 | 934.7290 | 936.1948 | 937.6616 | 939.1295 |
| 96..... | 940.5984 | 942.0683 | 943.5392 | 945.0111 | 946.4841 | 947.9581 | 949.4331 | 950.9091 | 952.3764 | 953.8545 |
| 97..... | 955.3336 | 956.8136 | 958.2948 | 959.7672 | 961.2503 | 962.7345 | 964.2099 | 965.6961 | 967.1735 | 968.6617 |
| 98..... | 970.1412 | 971.6314 | 973.1129 | 974.6051 | 976.0886 | 977.5829 | 979.0684 | 980.5548 | 982.0522 | 983.5407 |
| 99..... | 985.0302 | 986.5206 | 988.0220 | 989.5145 | 991.0080 | 992.5025 | 993.9980 | 995.4945 | 996.9920 | 998.4905 |
| 100..... | 1.000.0000 | | | | | | | | | |

*Rating table for Fourneyron turbines.*

McELWAIN'S FOURNEYRON.[a]

| Diameter of runner in inches. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | |
|---|---|---|---|---|---|---|
| | Horse-power. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (= P). | Discharge (= F). | Speed (= N). |
| 24..... | 13.05 | 480 | 220.5 | 0.203 | 2.000 | 55.10 |
| 30..... | 20.39 | 750 | 172.9 | .318 | 3.125 | 43.20 |
| 36..... | 29.37 | 1,080 | 143.9 | .458 | 4.500 | 35.90 |
| 42..... | 39.97 | 1,470 | 121.0 | .624 | 6.125 | 30.20 |
| 48..... | 52.22 | 1,920 | 106.0 | .815 | 8.000 | 26.50 |
| 54..... | 65.46 | 2,430 | 92.8 | 1.022 | 10.125 | 23.20 |
| 60..... | 81.60 | 3,000 | 83.5 | 1.275 | 12.500 | 20.80 |
| 66..... | 98.73 | 3,630 | 74.9 | 1.540 | 15.125 | 18.70 |
| 72..... | 117.50 | 4,320 | 68.6 | 1.833 | 18.000 | 17.10 |
| 84..... | 159.93 | 5,880 | 58.1 | 2.495 | 24.500 | 14.50 |
| 96..... | 208.89 | 7,680 | 50.3 | 3.259 | 32.000 | 12.50 |
| 108..... | 264.38 | 9,720 | 44.3 | 4.124 | 40.500 | 11.07 |
| 120..... | 326.40 | 12,000 | 39.6 | 5.092 | 50.000 | 9.90 |

[a] Formerly made by H. S. McElwain & Co., Amsterdam, N. Y. Mounted in a quarter-turn iron case, similar to the Boyden Fourneyron, with cylinder gate inside of guide ring.

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*Rating tables for scroll central-discharge turbines.*

JOHN TYLER IMPROVED.[a]

[1869 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (= P). | Discharge (= F). | Speed (= N). | | |
| 9 | 2 | 2.42 | 101 | 493 | 0.038 | 0.421 | 123.2 | 5 | |
| 12 | 2 | 4.24 | 177 | 363 | .066 | .738 | 90.7 | 10 | |
| 14 | 3 | 4.84 | 202 | 343 | .076 | .842 | 85.7 | 16 | |
| 18 | 9 | 10.90 | 456 | 246 | .170 | 1.901 | 61.5 | 36 | |
| 24 | 5 | 20.30 | 849 | 181 | .317 | 3.54 | 45.2 | 67 | |
| 30 | 2 | 30.30 | 1,267 | 144 | .473 | 5.296 | 36.0 | 100 | |
| 36 | 2 | 45.45 | 1,900 | 121 | .709 | 7.923 | 30.2 | 150 | |
| 42 | 2 | 60.60 | 2,534 | 104 | .945 | 10.55 | 26.0 | 200 | |
| 48 | 2 | 78.78 | 3,293 | 90 | 1.229 | 13.719 | 22.5 | 260 | |
| 60 | 2 | 121.20 | 5,068 | 72 | 1.891 | 21.141 | 18.0 | 400 | |
| 72 | 2 | 151.50 | 6,333 | 60 | 2.363 | 26.396 | 15.0 | 500 | |

REYNOLDS IMPROVED.[b]

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 12 | A. | | 48 | | 0.200 | | 200 |
| 12 | B. | | 80 | | .333 | | 200 |
| 12 | 1 | | 144 | | .600 | | 200 |
| 12 | 2 | | 180 | | .751 | | 200 |
| 15 | 1 | | 216 | | .901 | | 350 |
| 15 | 2 | | 276 | | 1.151 | | 350 |
| 18 | 1 | | 328 | | 1.367 | | 650 |
| 18 | 2 | | 408 | | 1.701 | | 650 |
| 18 | 3 | | 496 | | 2.067 | | 650 |
| 24 | 1 | | 652 | | 2.718 | | 1,200 |
| 24 | 2 | | 732 | | 3.052 | | 1,200 |
| 24 | 3 | | 876 | | 3.653 | | 1,200 |
| 30 | 1 | | 1,008 | | 4.205 | | 1,800 |
| 30 | 2 | | 1,208 | | 5.033 | | 1,800 |
| 30 | 3 | | 1,356 | | 5.654 | | 1,800 |
| 36 | 1 | | 1,320 | | 5.504 | | 2,700 |
| 36 | 2 | | 1,552 | | 6.467 | | 2,700 |
| 36 | 3 | | 1,980 | | 8.257 | | 2,700 |
| 42 | 2 | | 2,056 | | 8.574 | | 3,600 |
| 42 | 3 | | 2,288 | | 9.541 | | 3,600 |
| 48 | 2 | | 2,932 | | 12.226 | | 4,800 |
| 48 | 3 | | 3,296 | | 13.744 | | 4,800 |
| 48 | 4 | | 3,664 | | 15.279 | | 4,800 |
| 54 | 2 | | 3,960 | | 16.513 | | 6,000 |
| 54 | 3 | | 4,396 | | 18.321 | | 6,000 |
| 60 | 2 | | 4,580 | | 19.099 | | 8,600 |
| 60 | 3 | | 5,500 | | 22.935 | | 8,600 |

[a] Made by the Sullivan Machine Company, Claremont, N. H., usually with sliding gate in the throat, but also with a cylinder gate surrounding the runner within the scroll case. Has inward flow and discharges downward.

[b] Made by Kingsford Foundry and Machine Works, Oswego, N. Y. This turbine has an iron runner mounted in a boiler-iron scroll case, and a pivoted butterfly gate in the throat. The discharge is both upward and downward at the center, and the buckets protrude slightly from case.

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*Rating tables for scroll central-discharge turbines*—Continued.

CARLEY HELICAL WHEEL.[a]

[1889 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 15 | | 6.80 | 280 | 326 | 0.106 | 1.168 | 81.50 | 21 | |
| 18 | | 9.72 | 401 | 272 | .152 | 1.672 | 68.0 | 30 | |
| 21 | | 13.59 | 500 | 232 | .212 | 2.085 | 58.0 | 42 | |
| 24 | | 19.44 | 802 | 202 | .303 | 3.344 | 50.5 | 60 | |
| 28 | | 25.92 | 1,069 | 173 | .404 | 4.458 | 43.2 | 80 | |
| 36 | | 45.68 | 1,885 | 136 | .713 | 7.860 | 34.0 | 141 | |
| 50 | | 89.83 | 3,733 | 97 | 1.401 | 15.567 | 24.2 | 280 | |

PERFECTION STANDARD.[b]

[1894 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | | 1.32 | 49 | 806 | 0.021 | 0.204 | 201.5 | 3.5 | 100 |
| 8 | | 2.43 | 91 | 630 | .038 | .379 | 157.5 | 6.5 | 140 |
| 10 | | 3.70 | 157 | 480 | .058 | .655 | 120.0 | 9.0 | 200 |
| 12 | | 5.39 | 204 | 405 | .084 | .851 | 101.2 | 16.0 | 300 |
| 14 | | 7.83 | 284 | 350 | .122 | 1.184 | 87.5 | 21.0 | 400 |
| 16 | | 9.89 | 348 | 315 | .154 | 1.451 | 78.8 | 30.0 | 550 |
| 18 | | 11.94 | 482 | 276 | .186 | 2.010 | 69.0 | 36.0 | 700 |
| 21 | | 16.82 | 624 | 245 | .262 | 2.602 | 61.2 | 45.0 | 1,000 |
| 24 | | 20.99 | 785 | 206 | .327 | 3.273 | 51.5 | 64.0 | 1,100 |
| 27 | | 26.68 | 1,062 | 186 | .416 | 4.428 | 46.5 | 80.0 | 1,700 |
| 30 | | 32.92 | 1,310 | 167 | .514 | 5.463 | 41.8 | 100.0 | 2,000 |
| 36 | | 47.47 | 1,886 | 140 | .740 | 7.965 | 35.0 | 142.0 | 2,900 |
| 42 | | 67.90 | 2,715 | 120 | 1.059 | 11.322 | 30.0 | 203.0 | 4,500 |
| 48 | | 87.90 | 3,476 | 104 | 1.371 | 14.495 | 26.0 | 263.0 | 6,000 |
| 54 | | 110.80 | 4,426 | 93 | 1.728 | 18.456 | 23.2 | | |

DOUBLE PERFECTION WHEEL.[b]

[1894 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | | 1.32 | 49 | 806 | 0.021 | 0.204 | 201.5 | 7.0 | 175 |
| 8 | | 2.43 | 91 | 630 | .038 | .379 | 157.5 | 13.0 | 285 |
| 10 | | 3.70 | 157 | 480 | .058 | .655 | 120.0 | 18.0 | 475 |
| 12 | | 5.39 | 204 | 405 | .084 | .851 | 101.2 | 32.0 | 650 |
| 14 | | 7.83 | 284 | 350 | .122 | 1.184 | 87.5 | 42.0 | 950 |
| 16 | | 9.89 | 348 | 315 | .154 | 1.451 | 78.8 | 60.0 | 1,040 |
| 18 | | 11.94 | 482 | 276 | .186 | 2.010 | 69.0 | 72.0 | 1,500 |
| 21 | | 16.82 | 624 | 245 | .262 | 2.602 | 61.2 | 190.0 | 2,000 |
| 24 | | 20.99 | 785 | 206 | .327 | 3.273 | 51.5 | 128.0 | 2,180 |
| 27 | | 26.68 | 1,062 | 186 | .416 | 4.428 | 46.5 | 160.0 | 2,770 |
| 30 | | 32.92 | 1,310 | 167 | .514 | 5.463 | 41.7 | 200.0 | 3,290 |
| 36 | | 47.47 | 1,886 | 140 | .741 | 7.865 | 35.0 | 284.0 | |
| 42 | | 67.90 | 2,715 | 120 | 1.059 | 11.322 | 30.0 | 406.0 | |
| 48 | | 87.90 | 3,476 | 104 | 1.373 | 14.495 | 26.0 | | |
| 54 | | 110.80 | 4,426 | 93 | 1.728 | 18.456 | 23.2 | | |

[a] Made by Alexander, Bradley & Dunning, Syracuse, N. Y. Has an iron runner set in an iron scroll case, discharging both upward and downward, and a pivoted butterfly gate in throat of case. There are no guides. Similar wheels are known by the names "Mahler" and "Cushing."

[b] Made by Craig Ridgway & Son, Coatesville, Pa. This has an inward flow and downward discharge. The buckets are curved in line of radius and slightly curved in line of axis at bottom. The Double Perfection turbine has a division plate and discharges both upward and downward. It has a sliding gate in the throat of scroll case.

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*Rating tables for scroll central-discharge turbines*—Continued.

JONES LITTLE GIANT.[a]

[1890 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 6 | | 2.2 | 91 | 642 | 0.034 | 0.379 | 160.5 | 6.8 | |
| 8 | | 3.3 | 136 | 483 | .051 | .567 | 120.7 | 10.0 | 270 |
| 10½ | | 6.6 | 272 | 376 | .103 | 1.134 | 94.0 | 20.0 | 390 |
| 12 | | 9.9 | 409 | 321 | .154 | 1.706 | 80.2 | 30.0 | 525 |
| 14 | | 14.8 | 614 | 276 | .231 | 2.560 | 69.0 | 45.0 | 760 |
| 16 | | 18.2 | 750 | 242 | .284 | 3.128 | 60.5 | 56.0 | 950 |
| 18 | | 26.4 | 1,090 | 214 | .412 | 4.545 | 53.5 | 81.0 | 1,525 |
| 21 | | 34.6 | 1,431 | 184 | .540 | 5.967 | 46.0 | 107.0 | 1,950 |
| 24 | | 44.6 | 1,840 | 161 | .696 | 7.673 | 40.2 | 138.0 | 2,500 |
| 33 | | 79.2 | 3,270 | 121 | 1.236 | 13.636 | 30.2 | 245.0 | 4,800 |
| 45 | | 118.5 | 4,810 | 92 | 1.849 | 20.058 | 23.0 | | |

JONES LITTLE GIANT.[a]

[1900 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 8 | Double | 3.23 | 134 | 507 | 0.050 | 0.559 | 126.8 | 10 | |
| 10 | do | 6.48 | 267 | 381 | .101 | 1.113 | 95.2 | 20 | |
| 12 | do | 9.70 | 401 | 337 | .151 | 1.672 | 84.2 | 30 | |
| 14 | do | 13.61 | 562 | 288 | .212 | 2.344 | 74.0 | 42 | |
| 16 | do | 18.15 | 749 | 250 | .283 | 3.123 | 62.5 | 56 | |
| 18 | do | 25.94 | 1,070 | 224 | .405 | 4.462 | 56.0 | 80 | |
| 21 | do | 34.60 | 1,431 | 190 | .540 | 5.967 | 47.5 | 107 | |
| 24 | do | 45.30 | 1,872 | 169 | .707 | 7.806 | 42.2 | 140 | |
| 33 | do | 97.24 | 4,011 | 121 | 1.517 | 16.726 | 30.2 | 300 | |
| 44 | Single | 118.50 | 4,810 | 92 | 1.849 | 20.058 | 23.0 | 360 | |

[a] Made by Munson Brothers, Utica, N. Y. This wheel, as described in the trade list of 1890 is mounted in a scroll case with sliding gate in throat. The buckets are double curved and protrude from center of case. The runner has a division plate and discharges both at top and bottom of case. There are no guides. Wheels from similar patterns are made by J. C. Wilson & Co., Picton, Ontario. In 1895 Munson Brothers' patterns were destroyed by fire. The sizes and capacities of the new patterns, as shown by the later list, differ somewhat from the earlier ones, largely owing to their lower rating in efficiency. A peculiarity of the runner is a groove and swell forming a corrugation in the center of each bucket intended to guide the water through the wheel. Later wheels are also mounted in register-gate cases.



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*Rating tables for Jonval turbines.*

MCELWAIN JONVAL.[a]

[1871 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 12 | | 4.71 | 171 | 479 | 0.073 | 0.713 | 119.8 | | |
| 14 | | 5.79 | 214 | 406 | .090 | .892 | 101.5 | | |
| 16 | | 9.05 | 335 | 323 | .141 | 1.397 | 80.7 | | |
| 18 | | 12.69 | 471 | 300 | .198 | 1.964 | 75.0 | | |
| 20 | | 16.20 | 601 | 280 | .253 | 2.501 | 70.0 | | |
| 25 | | 21.74 | 807 | 230 | .338 | 3.365 | 57.5 | | |
| 28 | | 28.98 | 1,076 | 216 | .452 | 4.464 | 54.0 | | |
| 30 | | 38.04 | 1,413 | 202 | .593 | 5.892 | 50.5 | | |
| 38 | | 50.00 | 1,856 | 160 | .780 | 7.740 | 40.0 | 160 | |
| 44 | | 65.21 | 2,420 | 144 | 1.017 | 10.091 | 36.0 | 220 | |
| 48 | | 79.71 | 2,959 | 116 | 1.240 | 12.339 | 29.0 | 292 | |
| 50 | | 94.20 | 3,497 | 106 | 1.470 | 14.582 | 26.5 | | |
| 55 | | 115.94 | 4,304 | 101 | 1.809 | 17.948 | 25.2 | | |
| 60 | | 144.94 | 5,381 | 86 | 2.261 | 22.438 | 21.5 | | |
| 72 | | 217.41 | 8,061 | 73 | 3.392 | 33.614 | 18.2 | | |

BLOOMINGDALE, OR WAIT'S CHAMPION.[b]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | | 3.4 | 122 | 688 | 0.053 | 0.509 | 172.0 | 9 | |
| 13 | | 4.6 | 160 | 508 | 072 | .667 | 127.0 | 12 | |
| 17 | | 7.6 | 280 | 372 | .118 | 1.168 | 93.0 | 21 | |
| 21 | | 12.0 | 474 | 325 | .187 | 1.976 | 81.2 | 35 | |
| 24 | | 18.0 | 678 | 276 | .281 | 2.827 | 69.0 | 50 | |
| 27 | | 25.0 | 940 | 253 | .390 | 3.920 | 63.2 | 70 | |
| 30 | | 34.0 | 1,220 | 242 | .530 | 5.087 | 60.5 | 90 | |
| 36 | | 45.0 | 1,611 | 190 | .702 | 6.718 | 47.5 | 120 | |
| 40 | | 56.0 | 2,034 | 172 | .874 | 8.482 | 43.0 | 150 | |
| 44 | | 64.0 | 2,406 | 155 | .998 | 10.033 | 38.7 | 180 | |
| 48 | | 72.0 | 2.710 | 133 | 1.123 | 11.301 | 33.2 | 200 | |
| 54 | | 93.0 | 3,531 | 122 | 1.451 | 14.724 | 30.5 | 260 | |
| 60 | | 107.0 | 4,068 | 102 | 1.670 | 16.964 | 25.5 | 300 | |
| 72 | | 181.0 | 6,783 | 86 | 2.824 | 28.285 | 21.5 | 500 | |

[a] Made by H. S. McElwain & Co., Amsterdam, N. Y. Has outside register gate, similar to that of the Bodine Jonval.

[b] Made by McCarthy & Doremus Manufacturing Company, Sandy Hill, N. Y. Has cast-iron Jonval runner and guide ring. Not usually provided with a gate, but erected in an iron or wooden penstock having a gate in the throat. Wheels from similar patterns were made by the Sandy Hill (N. Y.) Iron and Brass Works and by Ryther & Pringle, Carthage, N. Y.

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*Rating tables for Jonval turbines*—Continued.

DIX IMPROVED JONVAL.[a]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 12 | | 4.13 | 160 | 491 | 0.064 | 0.669 | 122.7 | 12.0 | |
| 18 | | 10.33 | 401 | 327 | .161 | 1.676 | 81.7 | 30.5 | |
| 20 | | 13.77 | 535 | 294 | .215 | 2.223 | 73.5 | 40.0 | |
| 24 | | 19.28 | 749 | 270 | .301 | 3.121 | 67.5 | 56.0 | |
| 30 | | 30.99 | 1,203 | 216 | .484 | 5.012 | 54.0 | 90.0 | |
| 36 | | 46.49 | 1,805 | 164 | .726 | 7.521 | 41.0 | 135.0 | |
| 40 | | 55.09 | 2,139 | 147 | .861 | 8.912 | 36.7 | 160.0 | |
| 48 | | 77.48 | 3,008 | 123 | 1.210 | 12.533 | 30.7 | 225.0 | |
| 54 | | 96.41 | 3,744 | 109 | 1.504 | 15.600 | 27.2 | 280.0 | |
| 60 | | 120.51 | 4,679 | 108 | 1.880 | 19.496 | 27.0 | 350.0 | |
| 72 | | 172.17 | 6,685 | 90 | 2.686 | 27.854 | 22.5 | 500.0 | |

OSGOOD IMPROVED JONVAL.[b]

[1883 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | | 4.54 | 160 | 540 | 0.071 | 0.669 | 135.0 | 12.0 | |
| 18 | | 11.36 | 401 | 359 | .177 | 1.676 | 89.8 | 30.5 | |
| 20 | | 15.14 | 535 | 323 | .236 | 2.223 | 80.8 | 40.0 | |
| 24 | | 21.20 | 749 | 297 | .331 | 3.121 | 74.2 | 56.0 | |
| 30 | | 34.08 | 1,203 | 237 | .531 | 5.012 | 59.2 | 90.0 | |
| 36 | | 51.18 | 1,805 | 180 | .798 | 7.521 | 45.0 | 135.0 | |
| 40 | | 60.59 | 2,139 | 161 | .945 | 8.912 | 40.2 | 160.0 | |
| 48 | | 85.22 | 3,008 | 135 | 1.329 | 12.533 | 33.8 | 225.0 | |
| 54 | | 106.05 | 3,744 | 119 | 1.654 | 15.600 | 29.8 | 280.0 | |
| 60 | | 132.56 | 4,679 | 118 | 2.068 | 19.496 | 29.5 | 350.0 | |
| 72 | | 189.38 | 6,685 | 99 | 2.954 | 27.854 | 24.8 | 500.0 | |

BODINE JONVAL.[c]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | | 4.71 | 171 | 479 | 0.073 | 0.713 | 119.7 | 13 | 190 |
| 14 | | 5.79 | 214 | 406 | .090 | .892 | 101.5 | 13 | 260 |
| 16 | | 9.05 | 335 | 323 | .141 | 1.397 | 80.7 | 25 | 370 |
| 18 | | 12.69 | 471 | 300 | .198 | 1.964 | 75.0 | 35 | 490 |
| 20 | | 16.20 | 601 | 280 | .253 | 2.506 | 70.0 | 45 | 650 |
| 25 | | 21.74 | 807 | 230 | .339 | 3.365 | 57.5 | 60 | 980 |
| 27 | | 28.98 | 1,076 | 216 | .452 | 4.487 | 54.0 | 80 | 1,150 |
| 30 | | 38.04 | 1,413 | 202 | .593 | 5.892 | 50.5 | 105 | 1,350 |
| 35 | | 50.00 | 1,856 | 160 | .780 | 7.740 | 40.0 | 138 | 1,680 |
| 40 | | 65.21 | 2,420 | 144 | 1.017 | 10.091 | 36.0 | 180 | 2,075 |
| 45 | | 79.71 | 2,959 | 116 | 1.243 | 12.339 | 29.0 | 220 | 2,420 |
| 50 | | 94.20 | 3,497 | 106 | 1.470 | 14.582 | 26.5 | 260 | 3,000 |
| 55 | | 115.94 | 4,304 | 101 | 1.808 | 17.948 | 25.2 | 320 | 3,500 |
| 60 | | 144.94 | 5,381 | 86 | 2.261 | 22.439 | 21.5 | 400 | 4,000 |
| 72 | | 217.41 | 8,061 | 73 | 3.392 | 33.614 | 18.2 | 630 | 5,100 |

[a] Made by J. L. & S. B. Dix, Glens Falls, N. Y. This wheel has a cast-iron runner and guide ring. It has no case or gate, and is set in a penstock having a gate in the throat of the leading flume.

[b] Made by John Osgood, Fort Edward, N. Y. A cast-iron runner with guide ring is mounted in a wrought-iron penstock having a gate in the throat similar to that of the Chase Jonval.

[c] Made by Genesee Valley Manufacturing Company, successors to Bodine Manufacturing Company, Mount Morris, N. Y. Has a register gate over the guide chute entrance. The guides are thickened at the top, where they have a width equal to the breadth of the chute openings.

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*Rating tables for Jonval turbines*—Continued.

CHASE IMPROVED JONVAL.[a]

[1897 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 12 | Regular | 5.47 | 240.6 | 576 | 0.085 | 1.003 | 144.0 | 18 | ..... |
| 15 | ....do.... | 7.90 | 347.4 | 462 | .123 | 1.449 | 115.5 | 26 | ..... |
| 18 | ....do.... | 13.09 | 574.8 | 356 | .204 | 2.397 | 89.0 | 43 | ..... |
| 21 | ....do.... | 16.40 | 721.8 | 308 | .256 | 3.010 | 77.0 | 44 | ..... |
| 24 | ....do.... | 28.25 | 1,243.2 | 287 | .441 | 5.184 | 71.7 | 93 | ..... |
| 27 | ....do.... | 35.55 | 1,564.2 | 254 | .555 | 6.523 | 63.5 | 117 | ..... |
| 30 | ....do.... | 42.53 | 1,871.4 | 241 | .663 | 7.804 | 60.2 | 140 | ..... |
| 36 | ....do.... | 56.21 | 2,472.6 | 197 | .877 | 10.311 | 49.2 | 185 | ..... |
| 42 | ....do.... | 88.10 | 3,876.6 | 177 | 1.374 | 16.165 | 44.2 | 290 | ..... |
| 48 | ....do.... | 114.83 | 5,052.6 | 151 | 1.791 | 21.069 | 37.7 | 378 | ..... |
| 54 | ....do.... | 127.59 | 5,614.0 | 143 | 1.990 | 23.395 | 35.7 | 420 | ..... |
| 66 | ....do.... | 196.85 | 8,661.6 | 124 | 3.071 | 36.119 | 31.0 | 648 | ..... |
| 78 | ....do.... | 243.03 | 1,069.3 | 110 | 3.791 | 44.591 | 27.5 | 800 | ..... |
| 12 | Special.... | 8.64 | 379.0 | 658 | .135 | 1.58 | 164.5 | 28 | ..... |
| 15 | ....do.... | 15.80 | 694.0 | 528 | .246 | 2.894 | 132.0 | 52 | ..... |
| 18 | ....do.... | 24.23 | 1,069.0 | 411 | .378 | 4.458 | 102.7 | 80 | ..... |
| 21 | ....do.... | 31.16 | 1,369.0 | 367 | .486 | 5.709 | 91.7 | 102 | ..... |
| 24 | ....do.... | 42.37 | 1,864.0 | 328 | .661 | 7.773 | 82.0 | 140 | ..... |
| 27 | ....do.... | 53.33 | 2,346.0 | 290 | .832 | 9.783 | 72.5 | 175 | ..... |
| 30 | ....do.... | 60.59 | 2,673.0 | 276 | .945 | 11.146 | 69.0 | 200 | ..... |
| 36 | ....do.... | 82.06 | 3,609.0 | 233 | 1.280 | 15.050 | 58.2 | 270 | ..... |
| 42 | ....do.... | 126.86 | 5,581.0 | 201 | 1.979 | 23.273 | 50.2 | 417 | ..... |
| 48 | ....do.... | 151.45 | 6,683.0 | 186 | 2.363 | 27.868 | 46.5 | 500 | ..... |
| 54 | ....do.... | 178.80 | 7,891.0 | 173 | 2.778 | 32.905 | 43.2 | 590 | ..... |
| 66 | ....do.... | 303.00 | 13,366.0 | 142 | 4.727 | 55.736 | 35.5 | 1,000 | ..... |
| 78 | ....do.... | 436.32 | 19,248.0 | 128 | 6.806 | 80.264 | 32.0 | 1,440 | ..... |

[a] Made by Chase Turbine Manufacturing Company, Orange, Mass. This is a parallel downward-flow turbine having a runner like that of the Jonval wheel, but with vanes curved both axially and radially. The runner is mounted in a wrought-iron penstock with a wicket gate in the throat.

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*Rating tables for register-gate turbines.*

GATES CURTIS.[a]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 20 | Regular | 9.33 | 597 | | 0.295 | 3.146 | | 57.2 | |
| 20 | Register | 7.35 | 486 | | .232 | 2.561 | | 46.0 | |
| 25 | Regular | 14.54 | 923 | | .459 | 4.864 | | 88.0 | |
| 25 | Register | 11.30 | 748 | | .357 | 3.942 | | 71.0 | |
| 30 | Regular | 21.58 | 1,376 | | .682 | 7.252 | | 130.8 | |
| 30 | Register | 16.20 | 1,072 | | .512 | 5.649 | | 101.0 | |
| 35 | Regular | 32.16 | 2,051 | | 1.016 | 10.809 | | 193.7 | |
| 35 | Register | 22.04 | 1,458 | | .696 | 7.684 | | 138.0 | |
| 40 | Regular | 41.60 | 2,653 | | 1.315 | 13.981 | | 250.8 | |
| 40 | Register | 29.00 | 1,920 | | .916 | 10.118 | | 182.0 | |
| 48 | Regular | 62.07 | 3,960 | | 1.961 | 20.869 | | 374.4 | |
| 48 | Register | 40.69 | 2,693 | | 1.286 | 14.193 | | 255.0 | |
| 56 | Regular | 88.83 | 5,666 | | 2.807 | 29.860 | | 535.0 | |

ECLIPSE DOUBLE.[b]

[1883 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 8 | | 2.22 | 94 | 616 | 0.035 | 0.392 | 154.0 | 7.0 | |
| 10 | | 3.20 | 132 | 488 | .050 | .550 | 122.0 | 9.9 | |
| 12½ | | 5.51 | 227 | 395 | .086 | .946 | 98.5 | 17.0 | |
| 15 | | 7.20 | 297 | 327 | .112 | 1.238 | 81.8 | 22.3 | |
| 17½ | | 10.37 | 428 | 280 | 1.62 | 1.784 | 70.0 | 31.8 | 500 |
| 20 | | 17.52 | 721 | 244 | .273 | 3.006 | 61.0 | 53.6 | 675 |
| 25 | | 24.46 | 1,010 | 197 | .382 | 4.212 | 49.3 | 75.6 | 1,150 |
| 30 | | 33.55 | 1,384 | 164 | .523 | 5.771 | 41.0 | 103.6 | 1,800 |
| 35 | | 52.46 | 2,160 | 140 | .818 | 9.007 | 35.0 | 161.8 | 2,400 |
| 40 | | 67.36 | 2,778 | 122 | 1.051 | 11.584 | 30.5 | 208.0 | 3,300 |
| 48 | | 98.12 | 4,048 | 103 | 1.531 | 16.880 | 25.8 | 303.0 | 5,000 |
| 54 | | 128.16 | 5,293 | 91 | 2.000 | 22.072 | 22.8 | 396.0 | 6,725 |
| 60 | | 168.41 | 6,947 | 82 | 2.627 | 28.969 | 20.5 | 519.8 | 8,225 |
| 66 | | 214.10 | 8,818 | 74 | 3.340 | 36.771 | 18.5 | 660.0 | 10,000 |
| 72 | | 254.89 | 10,517 | 68 | 3.976 | 43.773 | 17.0 | 787.5 | 10,825 |

HELMER'S PATENT ROME.[c]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | | 7.00 | 300.0 | 426 | 0.109 | 1.250 | 106.5 | 22 | |
| 15 | | 10.50 | 450.0 | 355 | .161 | 1.875 | 88.7 | 33 | |
| 18 | | 14.00 | 600.0 | 284 | .218 | 2.500 | 71.0 | 45 | |
| 21 | | 21.44 | 900.0 | 248 | .335 | 3.750 | 62.0 | 67 | |
| 24 | | 28.88 | 1,200.0 | 213 | .451 | 5.000 | 53.2 | 90 | |
| 30 | | 46.54 | 1,920.0 | 170 | .726 | 8.000 | 42.5 | 144 | |
| 36 | | 64.00 | 2,640.0 | 142 | 1.000 | 11.000 | 35.5 | 198 | |
| 42 | | 84.02 | 3,466.2 | 122 | 1.310 | 14.442 | 30.5 | 260 | |
| 48 | | 108.56 | 4,479.6 | 106 | 1.694 | 18.665 | 26.5 | 336 | |

[a] Made by Gates Curtis, Ogdensburg, N.Y. A turbine of small capacity, commonly with an inside register gate. The water enters in an inward and downward direction and is discharged downward. The wheel closely resembles the Jonval type. According to the list the "regular" pattern of each size is built with cylinder gate.

[b] Made by Stillwell & Bierce Manufacturing Company, Dayton, Ohio. An inside register-gate turbine. The gate ring is of about the same thickness as the fixed outside guide ring. One-half of each guide is in the inner ring. The ends slide past each other in such manner as to give a continually contracting jet without sharp angles. The runner has central division plate. The buckets are curved slightly downward, but do not bulge outward.

[c] Made by S. Adams & Son, Rome, N.Y. A turbine of small capacity with inside register gate. Buckets curve radially, but discharge inward and downward.

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*Rating tables for register-gate turbines*—Continued.

CASE NATIONAL IMPROVED.[a]

[1898 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 5 | | 1.16 | 48 | 980 | 0.018 | 0.200 | 245.0 | 3.6 | 45 |
| 10 | | 2.77 | 112 | 550 | .043 | .467 | 137.0 | 8.4 | 250 |
| 10 | | 4.16 | 168 | 550 | .065 | .700 | 137.0 | 12.6 | 280 |
| 15 | | 7.14 | 288 | 362 | .111 | 1.201 | 90.5 | 21.6 | 530 |
| 15 | | 9.54 | 385 | 362 | .149 | 1.605 | 90.5 | 28.8 | 550 |
| 15 | | 11.92 | 481 | 362 | .186 | 2.006 | 90.5 | 36.0 | 600 |
| 20 | | 12.72 | 513 | 266 | .198 | 2.139 | 66.5 | 38.4 | 860 |
| 20 | | 15.89 | 641 | 266 | .248 | 2.673 | 66.5 | 48.0 | 880 |
| 20 | | 19.09 | 770 | 266 | .298 | 3.211 | 66.5 | 57.6 | 900 |
| 25 | | 23.26 | 938 | 208 | .363 | 3.911 | 52.0 | 70.2 | 1,500 |
| 25 | | 31.02 | 1,251 | 208 | .484 | 5.217 | 52.0 | 93.6 | 1,600 |
| 30 | | 31.57 | 1,273 | 174 | .492 | 5.308 | 43.5 | 96.0 | 2,000 |
| 30 | | 36.60 | 1,476 | 174 | .571 | 6.155 | 43.5 | 110.4 | 2,150 |
| 30 | | 43.35 | 1,708 | 174 | .675 | 7.122 | 43.5 | 127.8 | 2,200 |
| 40 | | 56.69 | 2,286 | 132 | .884 | 9.533 | 33.0 | 171.0 | 3,500 |
| 40 | | 69.61 | 2,807 | 132 | 1.086 | 11.705 | 33.0 | 210.0 | 3,700 |
| 40 | | 83.55 | 3,369 | 132 | 1.303 | 14.049 | 33.0 | 252.0 | 3,900 |
| 50 | | 124.32 | 5,013 | 106 | 1.932 | 20.904 | 26.5 | 375.0 | 7,000 |
| 50 | | 143.22 | 5,775 | 106 | 2.234 | 24.082 | 26.5 | 432.0 | 7,200 |
| 60 | | 167.10 | 6,738 | 90 | 2.607 | 28.097 | 22.5 | 504.0 | 12,000 |
| 60 | | 200.53 | 8,086 | 90 | 3.128 | 33.719 | 22.5 | 604.8 | 13,000 |

WETMORE.[b]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | | 5.49 | 213 | 457 | 0.085 | 0.888 | 114.2 | 16 | |
| 15 | | 8.34 | 333 | 366 | .130 | 1.388 | 91.5 | 25 | |
| 18 | | 11.70 | 467 | 305 | .182 | 1.947 | 76.2 | 35 | |
| 21 | | 17.41 | 695 | 260 | .272 | 2.898 | 65.0 | 52 | |
| 24 | | 24.47 | 976 | 228 | .382 | 4.070 | 57.0 | 73 | |
| 27 | | 30.16 | 1,203 | 201 | .471 | 5.016 | 50.2 | 90 | |
| 30 | | 37.70 | 1,497 | 182 | .589 | 6.242 | 45.5 | 112 | |
| 36 | | 54.29 | 2,167 | 153 | .848 | 9.036 | 38.2 | 162 | |
| 42 | | 81.44 | 3,251 | 130 | 1.272 | 13.566 | 32.5 | 243 | |
| 48 | | 112.20 | 4,479 | 114 | 1.753 | 18.677 | 28.5 | 334 | |
| 54 | | 137.09 | 5,472 | 101 | 2.142 | 22.818 | 25.2 | 409 | |
| 60 | | 191.38 | 7,639 | 91 | 2.990 | 31.855 | 22.7 | 571 | |

[a] Made by the Case Wheel and Mill Company, Bristol, Conn. This wheel has buckets of medium depth, moderately curved both in line of radius and parallel to axis, but not protruding below lower outside band of runner, which can be lifted from case vertically. Runner resembles that of the Swain turbine; has inside register gate. One-half of each quadrant of wheel is entirely closed, the other half contains four guides. The register gate fits against the closed portion of guide ring when wheel is open, leaving four openings opposite the guide chutes which are completely shut off one after another as register ring is moved over them.

[b] Made by Sullivan Machine Company, Claremont, N. H. This turbine has outside register gate. The buckets are large and the guide chutes few in number. The buckets are curved axially and radially, but do not protrude beyond the lower rim band of runner.

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*Rating tables for register-gate turbines*—Continued.

FLENNIKEN.[a]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 8 | | 2.76 | 115 | 760 | 0.043 | 0.480 | 190.0 | 8 | 130 |
| 10 | | 3.80 | 157 | 608 | .059 | .655 | 152.0 | 11 | 210 |
| 12 | | 5.58 | 234 | 506 | .087 | .976 | 126.5 | 16 | 333 |
| 14 | | 6.61 | 270 | 435 | .103 | 1.126 | 108.8 | 19 | 380 |
| 16 | | 8.74 | 367 | 380 | .136 | 1.530 | 95.0 | 25 | 460 |
| 18 | | 12.34 | 500 | 338 | .192 | 2.085 | 84.5 | 35 | 600 |
| 21 | | 15.34 | 669 | 304 | .239 | 2.790 | 76.0 | 47 | 800 |
| 22½ | | 19.35 | 794 | 270 | .302 | 3.311 | 67.5 | 55 | 940 |
| 25 | | 25.85 | 1,058 | 243 | .403 | 4.412 | 60.8 | 73 | 1,110 |
| 30 | | 34.34 | 1,406 | 203 | .536 | 5.863 | 50.8 | 96 | 1,500 |
| 35 | | 45.30 | 1,909 | 173 | .707 | 7.960 | 43.2 | 130 | 2,200 |
| 40 | | 65.15 | 2,678 | 152 | 1.016 | 11.167 | 38.0 | 182 | 2,900 |
| 45 | | 83.67 | 3,526 | 135 | 1.305 | 14.703 | 33.8 | 240 | 3,750 |
| 50 | | 118.99 | 4,948 | 122 | 1.856 | 20.633 | 30.5 | 336 | 5,000 |
| 55 | | 139.90 | 5,878 | 114 | 2.182 | 24.511 | 28.5 | 400 | 6,100 |
| 60 | | 184.73 | 7,554 | 102 | 2.882 | 31.500 | 25.5 | 514 | 7,300 |
| 72 | | 243.85 | 9,961 | 85 | 3.804 | 41.537 | 21.2 | 702 | 11,000 |

HUMPHREY STANDARD IXL.[b]

[1898 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | | 4.6 | 150 | 400 | 0.072 | 0.626 | 100.0 | | |
| 15 | | 7.1 | 236 | 320 | .1110 | .984 | 80.0 | | |
| 18 | | 10.2 | 340 | 267 | .160 | 1.418 | 66.7 | | |
| 21 | | 14.0 | 464 | 229 | .218 | 1.935 | 57.2 | | |
| 24 | | 18.3 | 604 | 200 | .285 | 2.519 | 50.0 | | |
| 27 | | 23.1 | 765 | 178 | .360 | 3.190 | 44.5 | | |
| 30 | | 28.5 | 945 | 160 | .445 | 3.941 | 40.0 | | |
| 33 | | 34.5 | 1,144 | 145 | .538 | 4.770 | 36.2 | | |
| 36 | | 41.1 | 1,360 | 133 | .641 | 5.671 | 33.2 | | |
| 42 | | 56.0 | 1,852 | 115 | .874 | 7.723 | 28.7 | | |
| 48 | | 73.1 | 2,420 | 100 | 1.142 | 10.091 | 25.0 | | |
| 54 | | 92.5 | 3,064 | 89 | 1.443 | 12.777 | 22.2 | | |
| 60 | | 114.2 | 3,780 | 80 | 1.782 | 15.763 | 20.0 | | |
| 68 | | 146.3 | 4,838 | 71 | 2.282 | 20.158 | 17.7 | | |
| 78 | | 195.0 | 6,450 | 62 | 3.042 | 26.897 | 15.5 | | |
| 88 | | 243.8 | 8,064 | 52 | 3.803 | 33.627 | 13.0 | | |
| 100 | | 318.7 | 10,550 | 48 | 4.972 | 43.994 | 12.0 | | |

[a] Made by Dubuque Turbine and Roller Mill Company, Dubuque, Iowa. An inside register-gate turbine of moderate capacity.

[b] See footnote (*a*) on following page.

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*Rating tables for register-gate turbines*—Continued.

HUMPHREY STANDARD XLCR.[a]

[1898 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 6 | | 2.3 | 75 | 800 | 0.036 | 0.313 | 200.0 | | |
| 8 | | 4.0 | 134 | 600 | .062 | .559 | 150.0 | | |
| 10 | | 6.3 | 210 | 480 | .098 | .876 | 120.0 | | |
| 12 | | 9.1 | 302 | 400 | .142 | 1.259 | 100.0 | | |
| 15 | | 14.3 | 473 | 320 | .223 | 1.972 | 80.0 | | |
| 18 | | 20.5 | 680 | 267 | .320 | 2.836 | 66.8 | | |
| 21 | | 28.0 | 926 | 229 | .437 | 3.861 | 57.2 | | |
| 24 | | 36.5 | 1,210 | 200 | .569 | 5.046 | 50.0 | | |
| 27 | | 46.2 | 1,532 | 178 | .721 | 6.388 | 44.5 | | |
| 30 | | 57.1 | 1,890 | 160 | .891 | 7.881 | 40.0 | | |
| 33 | | 69.0 | 2,288 | 145 | 1.076 | 9.541 | 36.2 | | |
| 36 | | 82.2 | 2,720 | 133 | 1.282 | 10.134 | 33.2 | | |
| 42 | | 112.0 | 3,704 | 115 | 1.747 | 15.446 | 28.8 | | |
| 48 | | 146.2 | 4,840 | 100 | 2.281 | 20.183 | 25.0 | | |
| 54 | | 185.0 | 6,064 | 89 | 2.886 | 25.287 | 22.2 | | |
| 60 | | 228.4 | 7,560 | 80 | 3.563 | 31.525 | 20.0 | | |
| 68 | | 292.6 | 9,676 | 71 | 4.565 | 40.349 | 17.8 | | |

BURNHAM'S NEW IMPROVED STANDARD.[b]

[1900 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 9 | | 4.41 | 178 | 540 | 0.068 | 0.742 | 135.0 | 13.3 | 160 |
| 10½ | | 6.03 | 244 | 463 | .094 | 1.017 | 115.8 | 18.3 | 185 |
| 12 | | 7.89 | 318 | 405 | .123 | 1.326 | 101.2 | 23.7 | 290 |
| 13½ | | 9.97 | 402 | 360 | .156 | 1.676 | 90.0 | 30.0 | 370 |
| 15 | | 12.30 | 497 | 324 | .192 | 2.072 | 81.0 | 37.3 | 450 |
| 16½ | | 14.88 | 600 | 295 | .231 | 2.502 | 73.8 | 44.8 | 580 |
| 18 | | 17.70 | 714 | 270 | .276 | 2.977 | 67.5 | 53.4 | 640 |
| 21 | | 24.11 | 972 | 232 | .376 | 4.053 | 58.0 | 72.7 | 956 |
| 24 | | 31.47 | 1,259 | 203 | .491 | 5.292 | 50.8 | 94.9 | 1,260 |
| 27 | | 39.87 | 1,608 | 180 | .622 | 6.705 | 45.0 | 120.3 | 1,600 |
| 30 | | 49.22 | 1,984 | 162 | .768 | 8.273 | 40.5 | 148.5 | 2,000 |
| 36 | | 70.90 | 2,859 | 135 | 1.106 | 11.922 | 33.8 | 213.7 | 2,850 |
| 42 | | 101.5 | 4,087 | 116 | 1.583 | 17.043 | 29.0 | 305.7 | 4,080 |
| 48 | | 131.1 | 5,289 | 101 | 2.045 | 22.055 | 25.2 | 395.4 | 6,000 |
| 54 | | 165.4 | 6,670 | 90 | 2.580 | 27.814 | 22.5 | 498.9 | 6,900 |
| 60 | | 203.4 | 8,203 | 82 | 3.173 | 34.206 | 20.5 | 613.5 | 8,900 |

[a] Made by Humphrey Machine Company, Keene, N. H. The IXL is a flume wheel. The XLCR is similar, but is mounted in pairs on horizontal shaft with central draft tube. A register ring of the ordinary type lies between the guide ring and runner. About this the guide ring revolves, giving in effect a register gate. The upper and lower rims of the guide ring are boldly curved, and the guide vanes are few and give long curved chutes. Manufacturers' power table is based on the theoretical power of the water, and the quantities are to be multiplied by an efficiency factor to get net power.

[b] Made by Burnham Brothers, York, Pa. This is an inside register-gate turbine. The buckets are not deep, and the vanes curve axially at bottom. The stated weights are for wheels with worm gate gearing.

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*Rating tables for register-gate turbines*—Continued.

BALANCED GATE.[a]

[1895 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 6 | | 1.86 | 76 | 790 | 0.029 | 0.317 | 197.5 | | |
| 8 | | 3.36 | 138 | 604 | .052 | .575 | 151.0 | | |
| 10 | | 5.28 | 217 | 486 | .082 | .905 | 121.5 | | 180 |
| 12 | | 7.66 | 312 | 406 | .119 | 1.301 | 101.5 | | 260 |
| 14 | | 10.38 | 426 | 348 | .162 | 1.776 | 87.0 | | 360 |
| 16 | | 13.60 | 558 | 306 | .212 | 2.327 | 76.5 | | 530 |
| 18 | | 17.27 | 708 | 274 | .269 | 2.952 | 68.5 | | 690 |
| 21 | | 23.58 | 967 | 236 | .368 | 4.032 | 59.0 | | 840 |
| 24 | | 31.85 | 1,267 | 206 | .497 | 5.283 | 51.5 | | 1,170 |
| 27 | | 39.28 | 1,606 | 184 | .613 | 6.697 | 46.0 | | 1,540 |
| 30 | | 48.78 | 1,988 | 166 | .761 | 8.290 | 41.5 | | 1,710 |
| 33 | | 58.87 | 2,410 | 150 | .918 | 10.050 | 37.5 | | 2,400 |
| 36 | | 70.74 | 2,874 | 138 | 1.104 | 11.984 | 34.5 | | 3,100 |
| 42 | | 96.74 | 3,930 | 120 | 1.509 | 16.388 | 30.0 | | 4,000 |
| 48 | | 127.1 | 5,164 | 105 | 1.983 | 21.534 | 26.2 | | 5,700 |
| 54 | | 161.8 | 6,574 | 94 | 2.524 | 27.414 | 23.5 | | 6,800 |
| 60 | | 200.6 | 8,150 | 85 | 3.129 | 33.986 | 21.25 | | 8,500 |
| 66 | | 243.8 | 9,908 | 77 | 3.803 | 41.316 | 19.2 | | 10,500 |
| 72 | | 291.4 | 11,804 | 72 | 4.546 | 49.223 | 18.0 | | 13,000 |

ALCOTT'S HIGH DUTY.[b]

[1898 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | Standard. | 4.1 | 160 | 484 | 0.064 | 0.667 | 121.0 | 12 | 165 |
| 10 | Special... | 9.95 | 397 | 484 | .155 | 1.655 | 121.0 | 30 | 275 |
| 12 | Standard. | 5.7 | 223 | 403 | .089 | .930 | 100.7 | 17 | 225 |
| 12 | Special... | 13.00 | 540 | 403 | .203 | 2.252 | 100.7 | 41 | 400 |
| 13 | Standard. | 7.2 | 281 | 378 | .112 | 1.172 | 94.5 | 21 | 275 |
| 13 | Special... | 16.45 | 681 | 378 | .257 | 2.840 | 94.5 | 51 | 475 |
| 15 | Standard. | 8.1 | 334 | 337 | .126 | 1.393 | 84.2 | 25 | 325 |
| 15 | Special... | 20.29 | 845 | 337 | .317 | 3.524 | 84.2 | 63 | 550 |
| 18 | Standard. | 12.2 | 508 | 276 | .190 | 2.118 | 69.0 | 38 | 500 |
| 18 | Special... | 29.25 | 1,217 | 276 | .456 | 5.075 | 69.0 | 91 | 850 |
| 21 | Standard. | 18.9 | 762 | 234 | .295 | 3.178 | 58.5 | 57 | 750 |
| 21 | Special... | 39.80 | 1,656 | 234 | .621 | 6.906 | 58.5 | 124 | 1,250 |
| 24 | Standard. | 24.8 | 968 | 209 | .387 | 4.036 | 52.2 | 73 | 950 |
| 24 | Special... | 52.00 | 2,164 | 209 | .811 | 9.024 | 52.2 | 162 | 1,600 |
| 27 | Standard. | 29.3 | 1,140 | 188 | .457 | 4.754 | 47.0 | 89 | 1,200 |
| 27 | Special... | 65.80 | 2,724 | 188 | 1.026 | 11.359 | 47.0 | 204 | 2,050 |
| 30 | Standard. | 43.9 | 1,818 | 166 | .685 | 7.581 | 41.5 | 137 | 1,800 |
| 30 | Special... | 81.17 | 3,381 | 166 | 1.266 | 14.099 | 41.5 | 253 | 3,050 |
| 30 | Medium.. | 62.0 | 2,406 | 166 | .967 | 10.033 | 41.5 | 180 | ..... |
| 36 | Standard. | 63.2 | 2,616 | 139 | .986 | 10.909 | 34.7 | 195 | 2,600 |

[a] Made by the Christiana Machine Company, Christiana, Pa. Has inside register gates. The buckets are nearly straight, curving slightly at the bottom.

[b] Made by T. C. Alcott & Son, Mount Holly, N. J., in regular and special styles. The regular style has a cylindrical runner similar to that of the Swain. The special style has bulging buckets extending the discharge area outside of nominal diameter, as in McCormick and Victor. Inside register gate.

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*Rating tables for register-gate turbines*—Continued.

ALCOTT'S HIGH DUTY—Continued.

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 36 | Special | 117.00 | 4,868 | 139 | 1.825 | 20.300 | 34.7 | 365 | 4,400 |
| 42 | Standard | 79.3 | 3,182 | 118 | 1.237 | 13.269 | 29.5 | 238 | 3,700 |
| 42 | Special | 159.20 | 6,624 | 118 | 2.484 | 27.622 | 29.5 | 495 | 6,300 |
| 48 | Standard | 117.5 | 4,742 | 103 | 1.833 | 19.774 | 25.7 | 354 | 5,000 |
| 48 | Special | 208.00 | 8,656 | 103 | 3.24 | 36.096 | 25.7 | 648 | 7,500 |
| 54 | | 174.5 | 6,958 | 92 | 2.722 | 29.015 | 23.0 | 531 | 5,800 |
| 60 | | 208.5 | 8,622 | 83 | 3.253 | 35.954 | 20.7 | 645 | 7,860 |
| 66 | | 278.2 | 11,450 | 76 | 4.340 | 47.746 | 19.0 | 869 | 9,300 |

LESNER'S IMPROVED.[a]

[1898 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5[b] | | 0.64 | 26.3 | 994 | 0.010 | 0.109 | 248.5 | 1.97 | |
| 8[b] | | 1.44 | 58.7 | 621 | .022 | .244 | 155.2 | 7.33 | |
| 8 | | 2.36 | 97.8 | 621 | .037 | .407 | 155.2 | 4.40 | |
| 8 | | | | | | | | 7.33 | |
| 11 | | 4.29 | 177.6 | 452 | .067 | .740 | 113.0 | 13.27 | |
| 11 | | 5.72 | 236.4 | 452 | .089 | .985 | 113.0 | 17.70 | |
| 14 | | 7.60 | 314.4 | 355 | .119 | 1.312 | 88.7 | 23.60 | |
| 16½ | | 7.44 | 307.8 | 302 | .116 | 1.282 | 75.5 | 23.05 | |
| 16½ | | 9.52 | 393.6 | 302 | .148 | 1.640 | 75.5 | 29.50 | |
| 18 | | 9.74 | 403.2 | 276 | .152 | 1.680 | 69.0 | 30.16 | |
| 18 | | 12.19 | 504.0 | 276 | .190 | 2.100 | 69.0 | 37.70 | |
| 18 | | 14.63 | 604.8 | 276 | .228 | 2.520 | 69.0 | 45.24 | |
| 22 | | 16.55 | 684.0 | 226 | .258 | 2.850 | 56.5 | 51.15 | |
| 22 | | 22.07 | 912.0 | 226 | .344 | 3.800 | 56.5 | 68.20 | |
| 22 | | 27.58 | 1,140.0 | 226 | .430 | 4.750 | 56.5 | 85.25 | |
| 28 | | 31.50 | 1,302.0 | 178 | .491 | 5.425 | 44.5 | 97.37 | |
| 28 | | 38.50 | 1,591.2 | 178 | .606 | 6.630 | 44.5 | 119.00 | |
| 33 | | 40.83 | 1,687.2 | 151 | .637 | 7.030 | 37.7 | 125.90 | |
| 33 | | 49.00 | 2,024.4 | 151 | .764 | 8.435 | 37.7 | 149.08 | |
| 36 | | 54.61 | 2,256.6 | 138 | .852 | 9.402 | 34.5 | 168.79 | |
| 36 | | 63.71 | 2,632.8 | 138 | .994 | 10.970 | 34.5 | 196.92 | |
| 44 | | 73.51 | 3,037.8 | 113 | 1.147 | 12.658 | 28.2 | 227.22 | |
| 44 | | 83.31 | 3,442.8 | 113 | 1.300 | 14.345 | 28.2 | 257.18 | |
| 56 | | 97.30 | 4,023.0 | 89 | 1.518 | 16.762 | 22.2 | 300.88 | |
| 56 | | 116.80 | 4,827.0 | 89 | 1.811 | 20.112 | 22.2 | 361.05 | |
| 56 | | 142.75 | 5,899.8 | 89 | 2.227 | 24.582 | 22.2 | 441.44 | |

[a] Made by Fultonville Foundry Company, successors to William B. Wemple's Sons, Fultonville, N.Y. This is an inside register-gate turbine, with buckets curving axially at bottom but not protruding below lower rim band of runner, which can be lifted out of the case vertically. This turbine has been extensively used to operate boat winches at locks on the Erie Canal.

[b] Brass runner for large heads.

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*Rating tables for register-gate turbines*—Continued.

RISDON CYLINDER- AND REGISTER GATE-TURBINES.[a]

[1896 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 12 | X. | 1.72 | 66.8 | 404 | 0.027 | 0.278 | 101.0 | 5.0 | |
| 12 | XX | 2.75 | 107.0 | 404 | .043 | .446 | 101.0 | 8.0 | |
| 12 | XXX | 3.39 | 140.0 | 404 | .053 | .584 | 101.0 | 10.5 | |
| 12 | Standard. | 4.80 | 187.0 | 404 | .075 | .780 | 101.0 | 14.0 | |
| 12 | T. C | 6.2 | 240.0 | 404 | .097 | 1.001 | 101.0 | 18.0 | |
| 12 | D. C | 7.20 | 281.0 | 404 | .112 | 1.172 | 101.0 | 21.0 | |
| 16 | Standard. | 7.20 | 281.0 | 314 | .112 | 1.172 | 78.5 | 21.0 | |
| 16 | T. C | 12.4 | 481.0 | 314 | .193 | 2.006 | 78.5 | 36.0 | |
| 16 | D. C | 14.40 | 562.0 | 314 | .225 | 2.344 | 78.5 | 42.0 | |
| 20 | Standard. | 12.4 | 481.0 | 264 | .193 | 2.006 | 66.0 | 36.0 | |
| 20 | T. C | 18.6 | 722.0 | 264 | .290 | 3.011 | 66.0 | 54.0 | |
| 20 | D. C | 24.8 | 962.0 | 264 | .387 | 4.012 | 66.0 | 72.0 | |
| 25 | Standard. | 18.6 | 722.0 | 218 | .290 | 3.011 | 54.5 | 54.0 | |
| 25 | T. C | 31.0 | 1,203.0 | 218 | .484 | 5.016 | 54.5 | 90.0 | |
| 25 | D. C | 43.0 | 1,669.0 | 218 | .671 | 6.960 | 54.5 | 125.0 | |
| 30 | Standard. | 31.0 | 1,203.0 | 188 | .484 | 5.016 | 47.0 | 90.0 | |
| 30 | T. C | 43.0 | 1,669.0 | 188 | .671 | 6.960 | 47.0 | 125.0 | |
| 30 | D. C | 68.0 | 2,646.0 | 188 | 1.061 | 11.034 | 47.0 | 200.0 | |
| 36 | Standard. | 43.0 | 1,669.0 | 157 | .671 | 6.960 | 39.2 | 125.0 | |
| 36 | T. C | 58.4 | 2,272.0 | 157 | .911 | 9.474 | 39.2 | 170.0 | |
| 36 | D. C | 96.2 | 3,743.0 | 157 | 1.500 | 15.608 | 39.2 | 280.0 | |
| 40 | Standard. | 58.4 | 2,272.0 | 142 | .911 | 9.474 | 35.5 | 170.0 | |
| 40 | T. C | 75.6 | 2,941.0 | 142 | 1.179 | 12.264 | 35.5 | 220.0 | |
| 40 | D. C | 116.8 | 4,544.0 | 142 | 1.825 | 18.948 | 35.5 | 340.0 | |
| 43 | Standard. | 75.6 | 2,941.0 | 132 | 1.179 | 12.264 | 33.0 | 220.0 | |
| 43 | T. C | 96.2 | 3,743.0 | 132 | 1.501 | 15.608 | 33.0 | 280.0 | |
| 43 | D. C | 151.2 | 5,882.0 | 132 | 2.359 | 24.528 | 33.0 | 440.0 | |
| 50 | Standard. | 96.2 | 3,743.0 | 113 | 1.501 | 15.608 | 28.2 | 280.0 | |
| 50 | T. C | 146.0 | 5,681.0 | 113 | 2.278 | 23.690 | 28.2 | 425.0 | |
| 50 | D. C | 192.4 | 7,486.0 | 113 | 3.001 | 31.217 | 28.2 | 560.0 | |
| 54 | Standard. | 120.3 | 4,671.0 | 105 | 1.877 | 19.478 | 26.2 | 350.0 | |
| 54 | T. C | 178.7 | 6,943.0 | 105 | 2.788 | 28.952 | 26.2 | 520.0 | |
| 54 | D. C | 240.6 | 9,342.0 | 105 | 3.753 | 38.956 | 26.2 | 700.0 | |
| 60 | Standard. | 146.0 | 5,681.0 | 94 | 2.278 | 23.690 | 23.5 | 425.0 | |
| 60 | T. C | 197.4 | 7,686.0 | 94 | 3.079 | 32.051 | 23.5 | 575.0 | |
| 60 | D. C | 292.0 | 11,362.0 | 94 | 4.556 | 47.380 | 23.5 | 850.0 | |
| 66 | Standard. | 178.7 | 6,943.0 | 86 | 2.788 | 28.952 | 21.5 | 520.0 | |
| 66 | T. C | 248.9 | 9,691.0 | 86 | 3.883 | 40.411 | 21.5 | 725.0 | |
| 66 | D. C | 357.4 | 13,886.0 | 86 | 5.575 | 57.905 | 21.5 | 1,040.0 | |
| 72 | Standard. | 223.4 | 8,688.0 | 78 | 3.485 | 36.229 | 19.5 | 650.0 | |
| 72 | T. C | 292.0 | 11,362.0 | 78 | 4.555 | 47.380 | 19.5 | 850.0 | |
| 72 | D. C | 446.8 | 7,376.0 | 78 | 6.970 | 30.758 | 19.5 | 1,300.0 | |

[a] Made by T. H. Risdon & Co., Mount Holly, N. J. The runner is similar to that of the Swain. The depth varies for each size according to capacity. Built both with register and with inside cylinder gate. The guide ring has no upper flange, and water is admitted from above as well as around the circumference.

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*Rating tables for pivot-gate turbines.*

CROCKER (NEW TYPE).[a]

[1901 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 15 | | 23.04 | 970 | 326 | 0.359 | 4.045 | 81.5 | 72 | 950 |
| 20 | | 41.6 | 1,710 | 258 | .649 | 7.131 | 64.5 | 129 | 1,670 |
| 25 | | 64.5 | 2,665 | 196 | 1.006 | 11,113 | 49.0 | 200 | 2,550 |
| 30 | | 94.0 | 3,250 | 164 | 1.466 | 13.552 | 41.0 | 288 | 4,360 |
| 35 | | 124.4 | 5,160 | 142 | 1.941 | 21.517 | 35.5 | 384 | 6,480 |
| 40 | | 167.3 | 6,940 | 127 | 2.610 | 28.940 | 31.7 | 512 | 8,850 |
| 43 | | 189.9 | 7,876 | 119 | 2.962 | 32.843 | 29.7 | 554 | 11,850 |
| 45 | | 205.0 | 8,500 | 114 | 3.198 | 35.445 | 28.5 | 640 | ..... |
| 50 | | 263.0 | 10,400 | 102 | 4.103 | 43.368 | 25.5 | 800 | ..... |
| 55 | | 311.0 | 12,830 | 95 | 4.852 | 53.501 | 23.7 | 960 | ..... |
| 60 | | 366.0 | 15,260 | 85 | 5.710 | 63.634 | 21.2 | 1,120 | ..... |

CROCKER (OLD TYPE).[a]

[1896 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15 | | 14.4 | 601 | 326 | 0.225 | 2.506 | 81.5 | 45 | ..... |
| 20 | | 25.9 | 1,070 | 258 | .404 | 4.462 | 64.5 | 80 | ..... |
| 25 | | 40.5 | 1,670 | 196 | .632 | 6.964 | 49.0 | 125 | ..... |
| 30 | | 58.4 | 2,406 | 164 | .911 | 10.033 | 41.0 | 180 | ..... |
| 35 | | 77.8 | 3,210 | 142 | 1.214 | 13.386 | 35.5 | 240 | ..... |
| 40 | | 104.8 | 4,345 | 127 | 1.635 | 18.119 | 31.7 | 320 | ..... |
| 45 | | 128.0 | 5,292 | 114 | 1.997 | 22.168 | 28.5 | 400 | ..... |
| 50 | | 162.4 | 6,700 | 102 | 2.533 | 27.939 | 25.5 | 500 | ..... |
| 55 | | 194.4 | 8,040 | 95 | 3.033 | 33.527 | 23.7 | 600 | ..... |
| 60 | | 228.8 | 9,435 | 85 | 3.569 | 39.344 | 21.2 | 700 | ..... |

CAMDEN HORIZONTAL.[b]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | | 10.3 | 401 | 489 | 0.161 | 1.672 | 122.2 | 30 | ..... |
| 18 | | 26.3 | 1,043 | 327 | .413 | 4.349 | 81.8 | 78 | ..... |
| 21 | | 28.7 | 1,149 | 280 | .448 | 4.791 | 70.0 | 86 | ..... |
| 24 | | 45.9 | 1,805 | 245 | .716 | 7.527 | 61.2 | 135 | ..... |
| 27 | | 61.3 | 2,418 | 218 | .956 | 10.083 | 54.5 | 181 | ..... |
| 30 | | 73.4 | 2,886 | 195 | 1.145 | 12.035 | 48.8 | 216 | ..... |
| 33 | | 83.4 | 3,286 | 177 | 1.301 | 13.702 | 44.2 | 246 | ..... |
| 36 | | 102.5 | 4,007 | 163 | 1.599 | 16.709 | 40.8 | 300 | ..... |

[a] Made by E. D. Jones & Sons Company, Pittsfield, Mass. This turbine has a small number of large gates pivoted near the circumference of the wheel. A short outrigger from each gate is connected to the turbine axis by a linkage, by means of which the gates are opened and closed. The later type of Crocker turbine has double curved buckets with ladle-shaped outlets protruding below and outside of the inlet ring.

[b] See footnote on following page.

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*Rating tables for pivot-gate turbines*—Continued.

CAMDEN VERTICAL.[a]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 12 | | 12.14 | 481 | 478 | 0.189 | 2.006 | 119.5 | 6 | |
| 18 | | 27.17 | 1,082 | 277 | .424 | 4.512 | 69.2 | 8 | |
| 21 | | 30.71 | 1,202 | 265 | .479 | 5.012 | 66.2 | 11 | |
| 24 | | 48.93 | 1,924 | 236 | .763 | 8.023 | 59.0 | 13 | |
| 27 | | 58.74 | 2,378 | 202 | .916 | 9.916 | 50.5 | 13 | |
| 30 | | 74.74 | 2,925 | 183 | 1.166 | 12.197 | 45.7 | 15 | |
| 33 | | 88.10 | 3,447 | 168 | 1.374 | 14.374 | 42.0 | 16 | |
| 36 | | 102.40 | 4,007 | 156 | 1.597 | 16.709 | 39.0 | 16 | |
| 42 | | 132.87 | 5,196 | 134 | 2.073 | 21.667 | 33.5 | 18 | |
| 48 | | 196.14 | 7,694 | 116 | 3.060 | 32.084 | 29.0 | 19 | |
| 54 | | 211.79 | 8,282 | 102 | 3.304 | 34.536 | 25.5 | 19 | |
| 60 | | 307.50 | 12,022 | 95 | 4.797 | 50.132 | 23.7 | 21 | |

CAMDEN STEEL DOUBLE.[a]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13 | | 3.43 | 133 | 631 | 0.054 | 0.555 | 157.7 | | |
| 12 | | 6.27 | 240 | 478 | .098 | 1.001 | 119.5 | | |
| 5½ | | 9.04 | 347 | 360 | .141 | 1.447 | 90.0 | | |
| 20 | | 16.76 | 642 | 275 | .261 | 2.667 | 68.7 | | |
| 23¼ | | 30.01 | 1,149 | 236 | .469 | 4.791 | 59.0 | | |
| 30 | | 64.68 | 2,471 | 183 | 1.009 | 10.304 | 45.7 | | |
| 36 | | 94.40 | 3,606 | 156 | 1.473 | 15.037 | 39.0 | | |
| 42 | | 114.70 | 4,382 | 134 | 1.789 | 18.273 | 33.5 | | |
| 48 | | 157.37 | 6,011 | 116 | 2.455 | 25.066 | 29.0 | | |
| 54 | | 239.26 | 9,150 | 102 | 3.735 | 38.156 | 25.5 | | |
| 60 | | 302.04 | 11,544 | 95 | 4.712 | 48.138 | 23.7 | | |

UNITED STATES.[a]

[1903 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15 | | 27.9 | 1,154 | 375 | 0.435 | 4.812 | 93.8 | 85 | |
| 18 | | 41.2 | 1,706 | 314 | .643 | 7.114 | 78.5 | 126 | |
| 21 | | 56.3 | 2,330 | 269 | .878 | 9.716 | 67.2 | 174 | |
| 24 | | 72.1 | 2,981 | 234 | 1.125 | 12.431 | 58.5 | 220 | |
| 27 | | 93.2 | 3,855 | 209 | 1.454 | 16.175 | 52.2 | 286 | |
| 30 | | 119.3 | 4,933 | 188 | 1.861 | 20.571 | 47.0 | 368 | |
| 33 | | 144.1 | 5,960 | 171 | 2.248 | 24.853 | 42.8 | 445 | |
| 36 | | 171.6 | 7,100 | 156 | 2.677 | 29.607 | 39.0 | 524 | |
| 39 | | 201.2 | 8,322 | 144 | 3.139 | 34.703 | 36.0 | 621 | |
| 42 | | 229.6 | 9,496 | 134 | 3.582 | 39.598 | 33.5 | 710 | |
| 45 | | 263.3 | 10,888 | 124 | 4.007 | 45.403 | 31.0 | 812 | |
| 48 | | 295.3 | 12,215 | 116 | 4.607 | 50.937 | 29.0 | 904 | |

[a] Made by Camden Water Wheel Works, Camden, N. Y. The Camden turbine is built with either pivot or register gates. The bucket ring is deep and narrow. The vanes are slightly ladle-shaped at bottom and broaden below lower rim band of runner. The Camden Horizontal turbine has two similar runners mounted on a horizontal shaft with central draft tube. The rating table is for a single runner. In the Camden Steel Double turbine the runner comprises a central dome having an upper ring of central-discharge buckets, the lower ring consisting of inward- and downward-flow buckets. The inlet ports to the latter are about one-half the depth of the frame. The buckets are curved axially and the outlet is at the bottom. The inner edge of the buckets is attached to the central drum. The United States turbine is a later type, having deep, bulging buckets and either cylinder or pivot gates.

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*Rating tables for pivot-gate turbines*—Continued.

COLE DOMINION.[a]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (= P). | Discharge (= F). | Speed (= N). | | |
| 12 | | 8.11 | | 459 | 0.126 | | 114.7 | 25 | |
| 15 | | 12.90 | | 367 | .201 | | 91.7 | 40 | |
| 18 | | 17.80 | | 306 | .278 | | 76.5 | 55 | |
| 21 | | 24.30 | | 265 | .379 | | 66.2 | 75 | |
| 24 | | 35 60 | | 229 | .556 | | 57.5 | 110 | |
| 27 | | 42.00 | | 204 | .655 | | 51.0 | 130 | |
| 30 | | 50.10 | | 183 | .782 | | 45.7 | 155 | |
| 36 | | 68.00 | | 153 | 1.061 | | 38.2 | 210 | |
| 42 | | 102.00 | | 131 | 1.591 | | 32.7 | 315 | |
| 48 | | 137.00 | | 114 | 2.137 | | 28.5 | 425 | |
| 54 | | 174.00 | | 102 | 2.714 | | 25.5 | 540 | |
| 60 | | 217.00 | | 91 | 3.385 | | 22.7 | 660 | |
| 66 | | 271.00 | | 83 | 4.321 | | 20.7 | 815 | |
| 72 | | 357.00 | | 76 | 5.476 | | 19.0 | 965 | |

BRADWAY.[b]

[1903 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | Standard | 5.20 | 212 | 441 | 0.081 | 0.884 | 110.2 | | |
| 15 | 3-in. bucket. | 9.40 | 365 | 344 | .147 | 1.522 | 86.0 | | |
| 15 | 5-in. bucket. | 15.65 | 497 | 344 | .244 | 2.072 | 86.0 | | |
| 18 | Standard | 22.79 | 895 | 276 | .356 | 3.732 | 69.0 | | |
| 20 | do | 25.31 | 900 | 250 | .395 | 3.753 | 56.2 | | |
| 24 | do | 30.38 | 1,120 | 208 | .474 | 4.467 | 52.0 | | |
| 27 | do | 42.60 | 1,580 | 186 | .665 | 6.588 | 46.5 | | |
| 30 | do | 50.29 | 1,930 | 166 | .785 | 8.048 | 41.5 | | |
| 36 | 12-in. bucket | 69.89 | 2,600 | 135 | 1.090 | 10.842 | 33.8 | | |
| 36 | Standard | 89.09 | 3,000 | 135 | 1.390 | 12.510 | 33.8 | | |
| 36 | Special | 104.75 | 3,790 | 138 | 1.634 | 15.804 | 34.5 | | |
| 42 | Standard | 118.20 | 4,650 | 124 | 1.844 | 19.390 | 31.0 | | |
| 48 | do | 167.00 | 6,122 | 104 | 2.605 | 25.528 | 26.0 | | |
| 48 | Special | 200.00 | 7,632 | 104 | 3.120 | 31.826 | 26.0 | | |

[a] Made by Vulcan Iron Works, Oswego, N. Y. A shallow wheel having inward discharge buckets, which curve, but do not bulge. The inner end of each of the pivoted guides is attached to the crown ring; the outward ring is actuated by linkages reaching from an outside gate ring to the ends of outriggers attached to the guides.

[b] Made by C. P. Bradway Machine Works, West Stafford, Conn. The runner is similar to that of the Swain. The gates are pivoted near the outer ends and open two, four, or six guide chutes at a time in successive sections, the remainder being closed.

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*Rating tables for pivot-gate turbines*—Continued.

BARTLEY WATER-TIGHT.[a]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 14 | Standard | 4.10 | 170 | 343 | 0.064 | 0.709 | 85.8 | | |
| 14 | Special | 10.00 | 414 | 343 | .156 | 1.726 | 85.8 | | |
| 16 | Standard | 6.30 | 259 | 300 | .098 | 1.080 | 75.2 | | |
| 16 | Special | 15.00 | 596 | 300 | .234 | 2.485 | 75.2 | | |
| 19 | Standard | 10.00 | 414 | 253 | .156 | 1.726 | 63.2 | | |
| 19 | Special | 20.00 | 805 | 253 | .312 | 3.357 | 63.2 | | |
| 22 | Standard | 15.00 | 596 | 218 | .234 | 2.485 | 54.5 | | |
| 22 | Special | 27.60 | 1,125 | 218 | .421 | 4.691 | 54.5 | | |
| 25 | Standard | 20.00 | 805 | 192 | .312 | 3.357 | 48.0 | | |
| 25 | Special | 36.00 | 1,492 | 192 | .562 | 6.222 | 48.0 | | |
| 29 | Standard | 27.00 | 1,125 | 166 | .421 | 4.691 | 41.5 | | |
| 29 | Special | 49.00 | 2,018 | 166 | .764 | 8.415 | 41.5 | | |
| 33 | Standard | 36.00 | 1,492 | 145 | .562 | 6.222 | 36.2 | | |
| 33 | Special | 60.00 | 2,746 | 145 | .936 | 11.450 | 36.2 | | |
| 38 | Standard | 49.00 | 2,018 | 126 | .764 | 8.415 | 31.5 | | |
| 38 | Special | 91.00 | 3,731 | 126 | 1.420 | 15.558 | 31.5 | | |
| 44 | Standard | 67.00 | 2,746 | 109 | 1.045 | 11.450 | 27.2 | | |
| 44 | Special | 91.00 | 3,731 | 109 | 1.420 | 15.558 | 27.2 | | |
| 51 | Standard | 91.00 | 3,731 | 94 | 1.420 | 15.558 | 23.5 | | |
| 51 | Special | 118.09 | 4,860 | 94 | 1.841 | 20.266 | 23.5 | | |
| 58 | Standard | 158.00 | 6,510 | 83 | 2.465 | 27.147 | 20.8 | | |
| 66 | do | 192.00 | 8,680 | 73 | 3.000 | 36.196 | 18.2 | | |
| 18 | 1900 pattern. | 30.20 | 1,310 | 300 | 0.471 | 5.463 | 75.0 | | |
| 21 | | 42.25 | 1,836 | 255 | .658 | 7.664 | 63.8 | | |
| 24 | | 53.00 | 2,280 | 212 | .827 | 9.508 | 53.0 | | |
| 30 | | 82.40 | 2,924 | 170 | 1.285 | 12.193 | 42.5 | | |
| 36 | | 118.00 | 5,140 | 140 | 1.841 | 21.434 | 35.0 | | |
| 42 | | 169.00 | 7,352 | 128 | 2.636 | 30.658 | 32.0 | | |
| 48 | No. 1 | 212.00 | 9,500 | 106 | 3.307 | 39.615 | 26.5 | | |
| 48 | No. 2 | 140.00 | 6,300 | 106 | 2.184 | 26.271 | 26.5 | | |

CANADA.[b]

[1895 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | | 5.88 | 232 | 432 | 0.092 | 0.967 | 108.0 | 17 | |
| 16 | | 10.60 | 419 | 324 | .165 | 1.747 | 81.0 | 31 | |
| 20 | | 16.32 | 646 | 259 | .255 | 2.694 | 64.7 | 47 | |
| 24 | | 24.10 | 954 | 216 | .376 | 3.978 | 54.0 | 71 | |
| 30 | | 36.14 | 1,431 | 173 | .564 | 5.967 | 43 2 | 108 | |
| 36 | | 53.02 | 2,099 | 144 | .827 | 8.753 | 36.0 | 159 | |
| 42 | | 73.60 | 2,914 | 123 | 1.148 | 12.151 | 30.7 | 218 | |
| 50 | | 103.83 | 4,111 | 104 | 1.620 | 17.143 | 26.0 | 304 | |
| 50 | | 103.83 | 4,111 | 104 | 1.620 | 17.143 | 26.0 | 304 | |
| 60 | | 170.53 | 6,752 | 87 | 2.660 | 28.156 | 21.7 | 494 | |

[a] Made by William Bartley & Sons, Bartley, N. J. The runner resembles that of the Swain. The flow is inward and downward. The buckets do not protrude below lower rim band of runner. The runner can be lifted vertically from case. The gates consist of semicircular columns, which are pivoted in a recess in the guide chutes and which turn half round, cutting off the guide opening.

[b] Made by Reading Foundry Company, Reading, Pa. This turbine has inward and downward flow. The buckets are curved, but are not bulging. The gates are few in nmuber, are pivoted near their inner ends, and are actuated by a gate ring surmounting the dome of the turbine.

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*Rating tables for pivot-gate turbines*—Continued.

ELMER WATER WHEEL.[a]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 10 | | 6.02 | 240 | 548 | 0.094 | 1.001 | 137.0 | | |
| 12.5 | | 9.37 | 374 | 438 | .146 | 1.560 | 109.5 | | |
| 15 | | 14.06 | 560 | 366 | .219 | 2.335 | 91.5 | | |
| 17.5 | | 19.07 | 760 | 319 | .297 | 3.169 | 79.7 | | |
| 20 | | 25.11 | 1,001 | 273 | .392 | 4.174 | 68.2 | | |
| 22.5 | | 31.46 | 1,254 | 244 | .491 | 5.229 | 61.0 | | |
| 25 | | 37.48 | 1,506 | 209 | .585 | 6.280 | 52.2 | | |
| 30 | | 56.24 | 2,204 | 182 | .877 | 9.191 | 45.5 | | |
| 35 | | 76.28 | 3,040 | 159 | 1.190 | 12.677 | 39.7 | | |
| 40 | | 100.44 | 4,004 | 137 | 1.567 | 16.697 | 34.2 | | |
| 45 | | 125.84 | 4,916 | 122 | 1.963 | 20.500 | 30.5 | | |
| 50 | | 149.92 | 6,024 | 109 | 2.339 | 25.120 | 27.2 | | |
| 55 | | 193.01 | 7,712 | 98 | 3.011 | 32.159 | 24.5 | | |
| 60 | | 224.26 | 8,960 | 92 | 3.498 | 37.363 | 23.0 | | |
| 65 | | 262.19 | 10,413 | 86 | 4.090 | 43.422 | 21.5 | | |

EUREKA IMPROVED.[b]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | | | | | | | | 5 | |
| 9 | | 4.82 | 182 | 507.0 | 0.075 | 0.759 | 126.8 | 14 | |
| 12 | | 6.79 | 281 | 472.0 | .106 | 1.172 | 118.0 | 21 | 353 |
| 15 | | 10.62 | 440 | 384.0 | .166 | 1.835 | 96.0 | 33 | 581 |
| 18 | | 13.20 | 546 | 319.0 | .206 | 2.277 | 79.8 | 41 | 775 |
| 21 | | 18.34 | 759 | 214.0 | .286 | 3.165 | 53.5 | 57 | 1,070 |
| 24 | | 26.41 | 1,092 | 240.0 | .412 | 4.554 | 60.0 | 82 | 1,770 |
| 27 | | 31.18 | 1,289 | 213.0 | .486 | 5.375 | 53.2 | 97 | 2,220 |
| 30 | | 42.18 | 1,744 | 192.0 | .658 | 7.272 | 48.0 | 131 | 2,400 |
| 36 | | 55.01 | 2,276 | 159.0 | .858 | 9.491 | 39.7 | 170 | 3,430 |
| 40 | | 66.00 | 2,730 | 144.0 | 1.030 | 11.384 | 36.0 | 204 | 4,022 |
| 48 | | 79.59 | 3,292 | 120.0 | 1.242 | 13.728 | 30.0 | 246 | 6,000 |
| 54 | | 107.10 | 4,430 | 106.0 | 1.671 | 18.473 | 26.5 | 334 | 8,600 |
| 60 | | 140.66 | 5,818 | 96.0 | 2.194 | 24.261 | 24.0 | 437 | 9,000 |
| 66 | | 183.39 | 7,585 | 87.0 | 2.816 | 31.629 | 21.7 | 567 | 12,220 |
| 72 | | 214.02 | 8,852 | 76.0 | 3.342 | 36.913 | 19.0 | 662 | 15,500 |
| 84 | | 324.00 | 13,370 | 65.6 | 5.054 | 55.753 | 16.4 | 1,000 | 18,000 |

[a] Made by Valley Iron Works Manufacturing Company, Appleton, Wis. A pivot-gate turbine, with outer ends of gates pivoted in frame, and inner ends moved by a gate ring. The buckets are curved along line of radius and have ladle-shaped outlets, not protruding much below lower band of runner. The wheel is of medium depth.

[b] Made by Allentown Foundry and Machine Works, Allentown, Pa. This turbine has an inside ring, similar to a register gate, to which the inner ends of the guides are pivoted. The outer ends slide on ways in the fixed outside guide ring. A very deep wheel.

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*Rating tables for pivot-gate turbines*—Continued.

SMITH IMPROVED SUCCESS.[a]

[1906 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 10 | No. 2 | 5.3 | 220 | 515 | 0.083 | 0.917 | 128.0 | 16.5 | |
| 10 | No. 1 | 3.5 | 147 | 515 | .055 | .613 | 128.0 | 11.0 | |
| 11½ | No. 2 | 7.5 | 311 | 448 | .117 | 1.297 | 112.0 | 23.3 | |
| 11½ | No. 1 | 4.9 | 207 | 448 | .076 | .863 | 112.0 | 15.5 | |
| 13 | No. 2 | 9.6 | 401 | 397 | .150 | 1.672 | 99.0 | 30.0 | |
| 13 | No. 1 | 6.4 | 267 | 397 | .998 | 1.113 | 99.0 | 20.0 | |
| 15 | No. 2 | 13.2 | 548 | 344 | .206 | 2.285 | 86.0 | 41.0 | |
| 15 | No. 1 | 8.8 | 367 | 344 | .137 | 1.530 | 86.0 | 27.5 | |
| 18 | No. 2 | 19.0 | 788 | 286 | .296 | 3.286 | 71.5 | 59.0 | |
| 18 | No. 1 | 12.5 | 528 | 286 | .195 | 2.202 | 71.5 | 39.5 | |
| 21 | No. 2 | 26.1 | 1,082 | 245 | .407 | 4.512 | 61.2 | 81.0 | |
| 21 | No. 1 | 17.3 | 721 | 245 | .270 | 3.006 | 61.2 | 54.0 | |
| 24 | No. 2 | 32.8 | 1,363 | 215 | .512 | 5.684 | 53.7 | 102.0 | |
| 24 | No. 1 | 21.9 | 909 | 215 | .342 | 3.790 | 53.7 | 68.0 | |
| 27 | No. 2 | 43.6 | 1,814 | 191 | .680 | 7.564 | 47.7 | 135.0 | |
| 27 | No. 1 | 29.0 | 1,208 | 191 | .452 | 5.016 | 47.7 | 90.0 | |
| 30 | No. 2 | 54.2 | 2,246 | 172 | 2.846 | 9.366 | 43.0 | 168.0 | |
| 30 | No. 1 | 36.1 | 1,497 | 172 | .563 | 6.242 | 43.0 | 112.0 | |
| 33 | No. 2 | 65.2 | 2,700 | 157 | 1.017 | 11.259 | 39.2 | 202.0 | |
| 33 | No. 1 | 43.6 | 1,804 | 157 | .680 | 7.523 | 39.2 | 135.0 | |
| 36 | No. 2 | 75.9 | 3,141 | 142 | 1.184 | 13.098 | 35.5 | 235.0 | |
| 36 | No. 1 | 50.7 | 2,099 | 142 | .791 | 8.753 | 35.5 | 157.0 | |
| 39 | No. 2 | 96.3 | 3,984 | 132 | 1.502 | 16.613 | 33.0 | 298.0 | |
| 39 | No. 1 | 64.6 | 2,674 | 132 | 1.008 | 11.150 | 33.0 | 200.0 | |
| 42 | No. 2 | 116.6 | 4,826 | 123 | 1.819 | 20.124 | 30.7 | 361.0 | |
| 42 | No. 1 | 77.8 | 3,222 | 123 | 1.214 | 13.436 | 30.7 | 241.0 | |
| 48 | No. 2 | 150.4 | 6,297 | 106 | 2.346 | 26.258 | 26.5 | 471.0 | |
| 48 | No. 1 | 100.8 | 4,198 | 106 | 1.572 | 17.506 | 26.5 | 314.0 | |
| 54 | No. 2 | 187.2 | 7,761 | 95 | 2.920 | 32.363 | 23.7 | 580.0 | |
| 54 | No. 1 | 124.8 | 5,174 | 95 | 1.947 | 21.576 | 23.7 | 387.0 | |
| 60 | No. 2 | 235.2 | 9,766 | 86 | 3.670 | 40.724 | 21.5 | 730.0 | |
| 60 | No. 1 | 156.8 | 6,511 | 86 | 2.446 | 27.151 | 21.5 | 487.0 | |
| 66 | No. 2 | 292.8 | 12,153 | 78 | 4.568 | 50.678 | 19.5 | 909.0 | |
| 66 | No. 1 | 195.2 | 8,102 | 78 | 3.045 | 33.785 | 19.5 | 606.0 | |
| 72 | No. 2 | 345.6 | 14,319 | 72 | 5.391 | 59.710 | 18.0 | 1,071.0 | |
| 72 | No. 1 | 230.4 | 9,546 | 72 | 3.594 | 39.807 | 18.0 | 714.0 | |

[a] Made by S. Morgan Smith Company, York, Pa. The Improved Success was built with two depths of bucket for each diameter, thus giving two capacities both with same speed. These were termed No. 1 and No. 2 respectively. The New Success is a later type of wheel. The Smith Success turbines have guides pivoted near their inner ends to the turbine case. The gates are opened and closed by pins on a sliding ring near the outer circumference of the case. The buckets are double curved, but do not project below lower ring of runner, which is of same diameter at bottom and top and may be lifted out of wheel case vertically.



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*Rating table for pivot-gate turbines*—Continued.

SMITH NEW SUCCESS.[a]

[1896 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 9 | | 8.5 | 354 | 584 | 0.132 | 1.476 | 146.0 | | |
| 12 | | 14.9 | 615 | 437 | .232 | 2.564 | 109.2 | | |
| 15 | | 23.7 | 982 | 350 | .369 | 4.095 | 87.5 | | |
| 18 | | 34.7 | 1,437 | 282 | .541 | 5.992 | 70.5 | | |
| 21 | | 49.1 | 2,033 | 269 | .766 | 8.478 | 67.2 | | |
| 24 | | 64.8 | 2,684 | 222 | 1.011 | 11.192 | 55.5 | | |
| 27 | | 82.1 | 3,399 | 207 | 1.281 | 14,174 | 51.7 | | |
| 30 | | 99.0 | 4,096 | 183 | 1.544 | 17.080 | 45.7 | | |
| 33 | | 121.5 | 5,025 | 159 | 1.895 | 20.954 | 39.7 | | |
| 36 | | 139.0 | 5,752 | 156 | 2.168 | 23.986 | 39.0 | | |
| 39 | | 163.5 | 6,762 | 134 | 2.556 | 28.198 | 33.5 | | |
| 42 | | 200.7 | 8,304 | 132 | 3.131 | 34.628 | 33.0 | | |
| 45 | | 213.7 | 8,842 | 119 | 3.324 | 36.871 | 29.7 | | |
| 48 | | 241.1 | 9,975 | 114 | 3.761 | 41.596 | 28.5 | | |
| 51 | | 274.6 | 11,357 | 108 | 4.284 | 47.359 | 27.0 | | |
| 54 | | 323.3 | 13,372 | 100 | 5.043 | 55.761 | 25.0 | | |
| 57 | | 362.7 | 15,022 | 97 | 5.658 | 62.642 | 24.2 | | |
| 60 | | 470.1 | 19,447 | 90 | 7.334 | 81.094 | 22.5 | | |
| 66 | | 568.9 | 23,530 | 82 | 8.875 | 98.008 | 20.5 | | |
| 72 | | 716.0 | 29,614 | 74 | 11.170 | 123.490 | 18.5 | | |
| 84 | | 975.1 | 40,323 | 64 | 15.210 | 168.147 | 16.0 | | |

AMERICAN.[b]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13 | | 5.30 | 219 | 378 | 0.083 | 0.913 | 94.5 | | |
| 16½ | | 8.00 | 332 | 296 | .125 | 1.384 | 74.0 | | |
| 20 | | 12.28 | 508 | 244 | .192 | 2.118 | 61.0 | | |
| 25 | | 19.67 | 813 | 195 | .307 | 3.390 | 48.8 | | |
| 30 | | 28.43 | 1,176 | 163 | .443 | 4.904 | 40.8 | | |
| 36 | | 46.48 | 1,924 | 136 | .725 | 8.023 | 34.0 | | |
| 42 | | 61.44 | 2,540 | 117 | .958 | 10.592 | 29.5 | | |
| 48 | | 79.10 | 3,271 | 102 | 1.234 | 13.640 | 25.5 | | |
| 54 | | 119.13 | 4,927 | 91 | 1.856 | 20.546 | 22.8 | | |
| 60 | | 155.89 | 6,448 | 82 | 2.434 | 26.888 | 20.5 | | |
| 66 | | 195.44 | 8,083 | 74 | 3.042 | 33.706 | 18.5 | | |
| 75 | | 245.87 | 10,170 | 65 | 3.838 | 42.409 | 16.3 | | |
| 84 | | 328.08 | 13,569 | 58 | 5.117 | 56.583 | 14.5 | | |

[a] See footnote on preceding page.

[b] Made by the Dayton Globe Iron Works Company, Dayton, Ohio. The American and New American turbines have runners of progressively increasing depth and capacity. The earlier types resemble the Swain; the later types resemble the McCormick. The gates comprise a fixed guide, forming the front wall of the chute, and a pivoted guide, forming the back wall. By swinging the latter, by means of a linkage device, the inlet is decreased or increased in size.

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*Rating table for pivot-gate turbines*—Continued.

NEW AMERICAN [a]

[1892 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 6 | | 3.2 | 134 | 818 | 0.05 | 0.559 | 204.5 | 10 | |
| 8 | | 5.5 | 227 | 614 | .086 | .946 | 153.5 | 17 | |
| 10 | | 8.1 | 334 | 490 | .126 | 1.393 | 122.5 | 25 | |
| 13 | | 11.1 | 508 | 378 | .173 | 2.118 | 94.5 | 38 | |
| 16 | | 22.7 | 908 | 306 | .354 | 3.786 | 76.5 | 67 | |
| 19 | | 29.4 | 1,216 | 258 | .459 | 5.071 | 64.5 | 91 | |
| 22 | | 35.8 | 1,482 | 222 | .558 | 6.180 | 55.5 | 111 | |
| 25 | | 39.0 | 1,616 | 195 | .608 | 6.739 | 48.7 | 121 | |
| 30 | | 63.2 | 2,616 | 163 | .986 | 10.909 | 40.7 | 195 | |
| 36 | | 81.5 | 3,369 | 136 | 1.271 | 14.049 | 34.0 | 252 | |
| 42 | | 122.7 | 5,074 | 117 | 1.914 | 21.158 | 29.2 | 300 | |
| 48 | | 141.8 | 5,864 | 102 | 2.212 | 24.453 | 25.5 | 439 | |
| 54 | | 208.5 | 8,622 | 91 | 3.256 | 35.954 | 22.7 | 645 | |
| 60 | | 271.1 | 11,216 | 82 | 4.230 | 46.771 | 20.5 | 839 | |
| 66 | | 347.5 | 14,378 | 74 | 5.421 | 59.956 | 18.5 | 1,076 | |
| 22 | Special | 40.0 | 1,657 | 222 | .624 | 6.910 | 55.5 | 124 | |
| 25 | do | 58.2 | 2,406 | 206 | .908 | 10.033 | 51.2 | 180 | |
| 36 | do | 105.6 | 4,382 | 136 | 1.647 | 18.273 | 34.0 | 328 | |
| 45 | do | 169.0 | 6,989 | 114 | 2.634 | 29.144 | 28.5 | 523 | |
| 54 | do | 238.2 | 9,841 | 99 | 3.716 | 41.037 | 24.75 | 737 | |

NEW AMERICAN.[a]

[1895 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13 | | 17.2 | 711 | 397 | 0.269 | 2.965 | 99.2 | | |
| 16 | | 28.8 | 1,153 | 321 | .449 | 4.808 | 80.2 | | |
| 19 | | 41.1 | 1,702 | 271 | .641 | 7.097 | 67.7 | | |
| 22 | | 53.7 | 2,227 | 234 | .838 | 9.286 | 58.5 | | |
| 25 | | 58.2 | 2,406 | 206 | .908 | 10.033 | 51.5 | | |
| 27½ | | 87.3 | 3,609 | 186 | 1.362 | 15.050 | 46.5 | | |
| 30 | | 99.5 | 4,120 | 171 | 1.552 | 17.180 | 42.7 | | |
| 33 | | 126.7 | 5,260 | 156 | 1.976 | 21.934 | 39.0 | | |
| 36 | | 144.9 | 5,994 | 143 | 2.260 | 24.995 | 35.7 | | |
| 39 | | 173.0 | 7,156 | 131 | 2.699 | 29.840 | 32.7 | | |
| 42 | | 207.4 | 8,582 | 123 | 3.235 | 35.787 | 30.7 | | |
| 45 | | 207.5 | 8,683 | 114 | 3.237 | 36.208 | 28.5 | | |
| 48 | | 234.0 | 9,679 | 107 | 3.650 | 40.361 | 26.7 | | |
| 51 | | 285.8 | 11,809 | 102 | 4.458 | 49.244 | 25.5 | | |
| 54 | | 329.9 | 13,630 | 97 | 5.146 | 56.837 | 24.2 | | |
| 57 | | 357.0 | 14,771 | 91 | 5.569 | 61.595 | 22.7 | | |
| 60 | | 399.6 | 16,535 | 86 | 6.234 | 68.951 | 21.5 | | |

[a] See footnote (*b*) on preceding page.

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*Rating tables for pivot-gate turbines*—Continued.

NEW AMERICAN.[a]

[1901 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 10 | | 11.3 | 467 | 490 | 0.176 | 1.947 | 122.5 | | 750 |
| 13 | | 17.2 | 711 | 397 | .268 | 2.965 | 99.2 | | 1,000 |
| 16 | | 28.8 | 1,153 | 321 | .449 | 4.808 | 80.2 | | 1,550 |
| 19 | | 41.1 | 1,702 | 271 | .641 | 7.097 | 67.7 | | 1,800 |
| 22 | | 53.7 | 2,227 | 234 | .838 | 9.286 | 58.5 | | 2,600 |
| 25 | | 67.5 | 2,790 | 206 | 1.053 | 11.634 | 51.5 | | 3,200 |
| 27½ | | 87.3 | 3,609 | 186 | 1.362 | 15.050 | 46.5 | | 4,000 |
| 30 | | 105.4 | 4,367 | 171 | 1.644 | 18.210 | 42.7 | | 4,800 |
| 33 | | 126.7 | 5,260 | 156 | 1.976 | 21.934 | 39.0 | | 6,000 |
| 36 | | 159.5 | 6,593 | 143 | 2.488 | 27.493 | 35.7 | | 7,500 |
| 39 | | 173.0 | 7,156 | 131 | 2.699 | 29.840 | 32.7 | | 8,500 |
| 42 | | 193.6 | 8,007 | 123 | 3.020 | 33.389 | 30.7 | | 9,300 |
| 45 | | 232.4 | 9,725 | 114 | 3.625 | 40.553 | 28.5 | | 10,000 |
| 48 | | 267.4 | 11,061 | 107 | 4.171 | 46.124 | 26.7 | | 11,500 |
| 51 | | 285.8 | 11,809 | 102 | 4.458 | 49.244 | 25.5 | | 14,600 |
| 54 | | 336.5 | 13,902 | 95 | 5.249 | 57.971 | 23.7 | | 17,500 |
| 57 | | 367.7 | 15,214 | 91 | 5.736 | 63.442 | 22.7 | | 20,000 |
| 60 | | 427.5 | 17,692 | 88 | 6.669 | 73.776 | 22.0 | | 22,500 |
| 72 | | 610.6 | 25,254 | 75 | 9.525 | 105.309 | 18.7 | | |
| 6 | (b) | 3.2 | 134 | 818 | .050 | .559 | 204.5 | | |
| 8 | (b) | 5.5 | 227 | 614 | .086 | .946 | 153.5 | | |
| 36 | (b) | 62.0 | 2,566 | 143 | .967 | 10.700 | 35.7 | | |
| 45 | (b) | 116.4 | 4,812 | 114 | 1.816 | 20.066 | 28.5 | | |

POOLE & HUNT LEFFEL TURBINE.[c]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7⅛ | 1 | 1.79 | 67 | 723 | 0.028 | 0.279 | 180.7 | | |
| 7⅛ | | 2.42 | 90 | 723 | .038 | .375 | 180.7 | | |
| 10 or 8¾ | 1 | 3.05 | 114 | 551 | .048 | .475 | 137.7 | | |
| 10 | | 4.13 | 154 | 551 | .064 | .642 | 137.7 | | |
| 13½ | 1 | 5.38 | 201 | 416 | .084 | .838 | 104.0 | | |
| 13½ | | 7.18 | 267 | 416 | .112 | 1.113 | 104.0 | | |
| 15½ | | 9.33 | 34. | 362 | .145 | 1.451 | 90.5 | | |
| 17½ | | 12.20 | 455 | 315 | .190 | 1.897 | 78.7 | | |
| 20 | | 16.15 | 602 | 276 | .252 | 2.510 | 69.0 | | |
| 23 | | 21.54 | 802 | 240 | .336 | 3.344 | 60.0 | | |
| 26½ | | 28.00 | 1,043 | 208 | .437 | 4.349 | 52.0 | | |
| 30½ | | 37.33 | 1,390 | 181 | .582 | 5.796 | 45.2 | | |
| 35 | | 49.17 | 1,831 | 158 | .767 | 7.635 | 39.5 | | |
| 40 | | 64.61 | 2,406 | 138 | 1.008 | 10.033 | 34.5 | | |
| 44 | | 75.30 | 2,209 | 126 | 1.175 | 9.212 | 31.5 | | |
| 48 | | 93.32 | 3,475 | 115 | 1.456 | 14.491 | 28.7 | | |
| 52 | | 121.32 | 4,518 | 110 | 1.893 | 18.840 | 27.5 | | |
| 56 | | 158.28 | 5,853 | 99 | 2.469 | 24.407 | 24.7 | | |
| 61 | | 186.64 | 6,950 | 90 | 2.912 | 28.982 | 22.5 | | |
| 66 | | 236.00 | 8,661 | 81 | 3.682 | 36.116 | 20.2 | | |

[a] See footnote (b) on page 114.
[b] Reduced discharge.
[c] Made by Poole & Hunt, Baltimore, Md. See footnote (a) on page 118.

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*Rating tables for pivot-gate turbines*—Continued.

TRUMP MODEL TURBINE.[a]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 14 | ..... | 23.90 | 989 | 385 | 0.373 | 4.124 | 96.2 | ..... | ..... |
| 17 | ..... | 41.8 | 1,724 | 317 | .652 | 7.189 | 79.2 | ..... | ..... |
| 20 | ..... | 58.3 | 2,406 | 269 | .909 | 10.033 | 67.2 | ..... | ..... |
| 23 | ..... | 77.4 | 3,195 | 234 | 1.207 | 13.323 | 58.5 | ..... | ..... |
| 26 | ..... | 100.0 | 4,131 | 204 | 1.560 | 17.226 | 51.0 | ..... | ..... |
| 30 | ..... | 131.0 | 5,428 | 177 | 2.044 | 22.635 | 44.2 | ..... | ..... |
| 35 | ..... | 179.5 | 7,407 | 154 | 2.800 | 30.887 | 38.5 | ..... | ..... |
| 40 | ..... | 232.8 | 9,606 | 134 | 3.632 | 40.057 | 33.5 | ..... | ..... |
| 44 | ..... | 282.3 | 11,645 | 121 | 4.404 | 48.560 | 30.2 | ..... | ..... |
| 48 | ..... | 335.7 | 13,851 | 112 | 5.237 | 57.759 | 28 | ..... | ..... |
| 52 | ..... | 394.0 | 16,257 | 103 | 6.146 | 67.792 | 25.7 | ..... | ..... |
| 56 | ..... | 457.3 | 18,865 | 96 | 7.134 | 78.667 | 24 | ..... | ..... |
| 61 | ..... | 544.2 | 22,401 | 88 | 8.489 | 93.412 | 22 | ..... | ..... |
| 66 | ..... | 635.2 | 26,205 | 82 | 9.909 | 109.275 | 20.5 | ..... | ..... |

LEFFEL (OLD TYPE.)[b]

[1892 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | Standard | 4.13 | 163 | 551 | 0.064 | 0.630 | 137.8 | ..... | ..... |
| 11½ | .....do..... | 5.38 | 213 | 479 | .084 | .888 | 119.8 | ..... | ..... |
| 13½ | .....do..... | 7.25 | 286 | 416 | .113 | 1.193 | 104 | ..... | ..... |
| 15½ | .....do..... | 9.38 | 370 | 362 | .146 | 1.543 | 90.5 | ..... | ..... |
| 17½ | .....do..... | 12.25 | 484 | 315 | .191 | 2.018 | 78.8 | ..... | ..... |
| 20 | .....do..... | 16 | 632 | 276 | .249 | 2.635 | 69 | ..... | ..... |
| 23 | .....do..... | 21.50 | 849 | 240 | .335 | 3.540 | 60 | ..... | ..... |
| 26½ | .....do..... | 28 | 1,106 | 208 | .437 | 4.612 | 52 | ..... | ..... |
| 30½ | .....do..... | 37.38 | 1,476 | 181 | .583 | 6.155 | 45.3 | ..... | ..... |
| 35 | .....do..... | 49 | 1,935 | 158 | .764 | 8.069 | 39.5 | ..... | ..... |
| 40 | .....do..... | 64.50 | 2,547 | 138 | 1.006 | 10.621 | 34.5 | ..... | ..... |
| 44 | .....do..... | 75 | 2,962 | 126 | 1.170 | 13.186 | 31.5 | ..... | ..... |
| 48 | .....do..... | 93 | 3,670 | 113 | 1.451 | 15.304 | 28.3 | ..... | ..... |
| 56 | .....do..... | 158 | 6,241 | 99 | 2.465 | 26.025 | 24.8 | ..... | ..... |
| 61 | .....do..... | 187 | 7,386 | 90 | 2.917 | 30.800 | 22.5 | ..... | ..... |
| 66 | .....do..... | 224 | 8,848 | 82 | 3.494 | 36.896 | 20.5 | ..... | ..... |
| 74 | .....do..... | 273 | 10,783 | 74 | 4.259 | 44.965 | 18.5 | ..... | ..... |
| 20 | Special..... | 23.25 | 916 | 276 | .363 | 3.820 | 69 | ..... | ..... |
| 23 | .....do..... | 31.13 | 1,229 | 240 | .486 | 5.125 | 60 | ..... | ..... |
| 26½ | .....do..... | 40.50 | 1,600 | 208 | .632 | 6.672 | 52 | ..... | ..... |
| 30½ | .....do..... | 54.25 | 2,143 | 181 | .850 | 8 936 | 45.3 | ..... | ..... |
| 35 | .....do..... | 71 | 2,804 | 158 | 1.108 | 11.693 | 39.5 | ..... | ..... |
| 40 | .....do..... | 93 | 3,672 | 138 | 1.451 | 15.312 | 34.5 | ..... | ..... |
| 44 | .....do..... | 109 | 4,305 | 126 | 1.700 | 17.952 | 31 5 | ..... | ..... |
| 50 | .....do..... | 144 | 5,688 | 113 | 2.246 | 23.719 | 28.3 | ..... | ..... |
| 56 | .....do..... | 183 | 7,228 | 99 | 2.855 | 30.141 | 24.8 | ..... | ..... |
| 61 | .....do..... | 217 | 8,571 | 90 | 3.385 | 35.741 | 22.5 | ..... | ..... |
| 66 | .....do..... | 255 | 10,072 | 82 | 3.971 | 42.000 | 20.5 | ..... | ..... |
| 74 | .....do..... | 306 | 12,087 | 74 | 4.774 | 50.403 | 18.5 | ..... | ..... |

[a] Made by the Trump Manufacturing Company, Springfield, Ohio. This wheel has pivot gates similar to the Leffel turbines. The inlet portion of the runner is a frustum of a cone, so that the water has an inward and downward direction as it enters the wheel.

[b] See footnote (*a*) on following page.

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*Rating tables for pivot-gate turbines*—Continued.

LEFFEL (NEW TYPE).[a]

[1900 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 10.... | Standard... | 3.70 | 53 | 535 | 0.058 | 0.220 | 133.8 | ..... | ..... |
| 11½... | .....do..... | 4.9 | 201 | 463 | .076 | .838 | 115.8 | ..... | ..... |
| 13½... | .....do..... | 6.5 | 267 | 404 | .101 | 1.113 | 101.0 | ..... | ..... |
| 15½... | .....do..... | 8.4 | 348 | 351 | .131 | 1.451 | 87.8 | ..... | ..... |
| 17½... | .....do..... | 11.00 | 455 | 306 | .172 | 1.897 | 76.5 | ..... | ..... |
| 20.... | .....do..... | 14.9 | 602 | 268 | .232 | 2.510 | 67 | ..... | ..... |
| 23.... | .....do..... | 19.4 | 802 | 233 | .303 | 3.344 | 58.2 | ..... | ..... |
| 26½... | .....do..... | 25.25 | 1,043 | 202 | .393 | 4.339 | 50.5 | ..... | ..... |
| 30½... | .....do..... | 33.61 | 1,390 | 176 | .524 | 5.796 | 44 | ..... | ..... |
| 35.... | .....do..... | 44.3 | 1,831 | 153 | .691 | 7.635 | 38.2 | ..... | ..... |
| 40.... | .....do..... | 58.2 | 2,406 | 134 | .908 | 10.033 | 33.5 | ..... | ..... |
| 44.... | .....do..... | 67.75 | 2,800 | 122 | 1.058 | 11.676 | 30.5 | ..... | ..... |
| 48.... | .....do..... | 84.1 | 3,475 | 110 | 1.312 | 14.490 | 27.5 | ..... | ..... |
| 56.... | .....do..... | 142 | 5,858 | 96 | 2.215 | 24.428 | 24 | ..... | ..... |
| 61.... | .....do..... | 168 | 6,950 | 87 | 2.621 | 28.982 | 21.8 | ..... | ..... |
| 66.... | .....do..... | 202 | 8,340 | 80 | 3.151 | 34.778 | 20 | ..... | ..... |
| 74.... | .....do..... | 247 | 10,222 | 72 | 3.853 | 42.623 | 18 | ..... | ..... |
| 20.... | Special..... | 21.13 | 870 | 268 | .329 | 3.628 | 67 | ..... | ..... |
| 23.... | .....do..... | 28.25 | 1,168 | 233 | .440 | 4.871 | 58.2 | ..... | ..... |
| 26½... | .....do..... | 36.8 | 1,520 | 202 | .574 | 6.338 | 50.5 | ..... | ..... |
| 30½... | .....do..... | 49.3 | 2,036 | 176 | .769 | 8.490 | 44 | ..... | ..... |
| 35.... | .....do..... | 64.4 | 2,664 | 153 | 1.005 | 11.089 | 38.2 | ..... | ..... |
| 40.... | .....do..... | 84.4 | 3,488 | 134 | 1.317 | 14.545 | 33.5 | ..... | ..... |
| 41.... | .....do..... | 98.9 | 4,090 | 122 | 1.543 | 17.055 | 30.5 | ..... | ..... |
| 50.... | .....do..... | 131 | 5,404 | 110 | 2.044 | 22.535 | 27.5 | ..... | ..... |
| 56.... | .....do..... | 166 | 6,867 | 96 | 2.590 | 28.635 | 24 | ..... | ..... |
| 61[b]... | .....do..... | 81.7 | 6,004 | 66 | 3.023 | 33.355 | 22 | ..... | ..... |
| 66.... | .....do..... | 98 | 7,205 | 56 | 3.626 | 39.913 | 18.7 | ..... | ..... |
| 74.... | .....do..... | 118 | 8,672 | 54 | 4.366 | 48.108 | 18 | ..... | ..... |

[a] Made by James Leffel & Co., Springfield, Ohio. The Leffel double turbine has two independent sets of buckets, one an inward and downward, the other a central discharge. Both receive water from the same set of guides but discharge it independently. The power table given for the Poole & Hunt Leffel (p. 116) is nearly identical with those issued by the Leffel Company in 1879, and for the corresponding sizes is the same as for the Trump Leffel (p. 117). The table for the Leffel of 1892 differs slightly from the preceding but agrees substantially with that in the 1897 list in which are rated new sizes of wheels having greater capacity. The Samson follows with further increase of capacity.

[b] At 9-foot head.

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*Rating tables for pivot-gate turbines*—Continued.

LEFFEL IMPROVED SAMSON.[a]

[1897 and 1900 lists.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 20 | | 51.7 | 2,111 | 325 | 0.806 | 8.803 | 81.3 | | |
| 23 | | 68.3 | 2,792 | 283 | 1.065 | 11.643 | 70.8 | | |
| 26 | | 87.3 | 3,569 | 250 | 1.362 | 14.883 | 62.5 | | |
| 30 | | 116 | 4,751 | 217 | 1.810 | 19.812 | 54.3 | | |
| 35 | | 158 | 6,440 | 186 | 2.465 | 26.855 | 46.5 | | |
| 40 | | 207 | 8,446 | 163 | 3.229 | 35.220 | 40.8 | | |
| 45 | | 262 | 10,689 | 145 | 4.087 | 44.573 | 36.3 | | |
| 50 | | 324 | 13,196 | 130 | 5.054 | 55.027 | 32.5 | | |
| 56 | | 405 | 16,554 | 116 | 6.318 | 69.030 | 29.0 | | |
| 62 | | 497 | 20,292 | 105 | 7.753 | 84.618 | 26.3 | | |
| 68 | | 597 | 24,409 | 96 | 9.313 | 101.786 | 24.0 | | |
| 74 | | 708 | 28,906 | 88 | 11.045 | 120.538 | 22.0 | | |
| 17 E. | | 14.3 | 581 | 373 | .223 | 2.423 | 93.2 | | |
| 17 D. | | 18.6 | 758 | 373 | .290 | 3.161 | 93.2 | | |
| 17 C. | | 24.5 | 998 | 373 | .382 | 4.162 | 93.2 | | |
| 17 B. | | 30.2 | 1,232 | 372 | .471 | 5.137 | 93.0 | | |
| 17 A. | | 39.5 | 1.610 | 372 | .616 | 6.714 | 93.0 | | |

*Rating tables for cylinder-gate turbines.*

ROCHESTER.[b]

[1873 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (= P). | Discharge (= F). | Speed (= N). | | |
| 16 | Standard | 6.44 | 267 | 319 | 0.100 | 1.113 | 79.8 | 20 | 450 |
| 20 | do | 10.68 | 440 | 271 | .166 | 1.835 | 67.8 | 33 | 950 |
| 20 | Special | 12.94 | 535 | | .202 | 2.231 | | 40 | |
| 25 | Standard | 16.17 | 667 | 199 | .252 | 2.781 | 49.8 | 50 | 1,650 |
| 25 | Special | 19.40 | 802 | | .303 | 3.344 | | 60 | |
| 30 | Standard | 24.25 | 1,003 | 162 | .378 | 4.182 | 40.5 | 75 | 2,100 |
| 30 | Special | 30.72 | 1,270 | | .479 | 5.296 | | 95 | |
| 36 | Standard | 40.45 | 1,669 | 152 | .631 | 6.960 | 38.0 | 125 | 2,700 |
| 36 | Special | 48.51 | 2,003 | | .757 | 8.353 | | 150 | |
| 42 | Standard | 64.68 | 2,670 | 126 | 1.010 | 11.134 | 31.5 | 200 | 3,600 |
| 48 | do | 80.90 | 3,339 | 99 | 1.262 | 13.924 | 24.8 | 250 | 4,200 |
| 54 | do | 103.60 | 4,275 | 89 | 1.616 | 17.827 | 22.2 | 320 | 5,100 |
| 60 | do | 113.20 | 4,671 | 84 | 1.766 | 19.478 | 21.0 | 350 | 6,200 |
| 66 | do | 145.60 | 6,007 | 81 | 2.271 | 25.049 | 20.2 | 450 | 7,400 |
| 72 | do | 186.10 | 7,677 | 79 | 2.903 | 32.013 | 19.8 | 575 | 8,500 |

[a] See footnote (a) on page 118.

[b] Formerly made by Rochester Turbine Manufacturing Company, Rochester, N. Y. The buckets were of small depth.

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*Rating tables for cylinder-gate turbines*—Continued.

SWAIN.[a]

[1897 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 12 | | 10.840 | 439.8 | 441 | 0.169 | 0.031 | 110.2 | | |
| 18 | | 24.390 | 989.4 | 294 | .380 | .069 | 73.5 | | |
| 21½ | | 35.570 | 1,444.2 | 249 | .555 | .100 | 62.2 | | |
| 24 | | 43.370 | 1,761.0 | 220 | .676 | .122 | 55.0 | | |
| 27½ | | 58.275 | 2,365.9 | 194 | .909 | .164 | 48.5 | | |
| 30 | | 72.110 | 2,927.6 | 176 | 1.125 | .203 | 44.0 | | |
| 36 | | 103.720 | 4,210.9 | 147 | 1.618 | .293 | 36.8 | | |
| 42 | | 141.260 | 5,734.9 | 126 | 2.204 | .398 | 31.5 | | |
| 48 | | 184.720 | 7,499.4 | 110 | 2.882 | .521 | 27.5 | | |
| 54 | | 237.070 | 9,625.2 | 98 | 3.698 | .485 | 24.5 | | |
| 60 | | 293.380 | 11,910.6 | 88 | 4.577 | .828 | 22.0 | | |
| 66 | | 357.580 | 14,517.6 | 80 | 5.578 | 1.009 | 20.0 | | |
| 72 | | 433.650 | 17,605.8 | 74 | 6.765 | 1.224 | 18.5 | | |
| 80 | | 530.450 | 21,535.8 | 66 | 8.275 | 1.497 | 16.5 | | |

DOLAN'S LITTLE GIANT.[b]

[1893 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | | 4.11 | 160 | 882 | 0.064 | 0.667 | 220.5 | 12.3 | 278 |
| 8 | | 7.39 | 288 | 750 | .115 | 1.201 | 187.5 | 23.0 | 375 |
| 10 | | 11.36 | 442 | 518 | .177 | 1.843 | 129.5 | 33.6 | 485 |
| 12 | | 17.37 | 655 | 414 | .271 | 2.731 | 103.5 | 49.0 | 650 |
| 14½ | | 24.11 | 909 | 345 | .376 | 3.790 | 86.5 | 68.0 | 875 |
| 17½ | | 29.78 | 1,123 | 283 | .464 | 4.683 | 70.7 | 84.0 | 1,250 |
| 20 | | 41.84 | 1,578 | 247 | .653 | 6.580 | 61.7 | 118.0 | 1,450 |
| 23 | | 54.94 | 2,072 | 214 | .857 | 8.640 | 53.5 | 155.0 | 1,650 |
| 27 | | 83.71 | 3,155 | 186 | 1.306 | 13.156 | 46.5 | 236.0 | 2,200 |
| 31 | | 95.72 | 3,610 | 160 | 1.493 | 15.054 | 40.0 | 270.0 | 2,500 |
| 36 | | 130.21 | 4,920 | 141 | 2.031 | 20.516 | 35.2 | 368.0 | 3,600 |
| 40 | | 157.25 | 6,150 | 130 | 2.453 | 25.646 | 32.5 | 460.0 | 5,000 |
| 44 | | 190.84 | 7,219 | 113 | 2.977 | 30.103 | 28.2 | 540.0 | 5,700 |
| 40 | | 239.27 | 9,024 | 104 | 3.733 | 37.630 | 26.0 | 675.0 | 8,400 |
| 58 | | 262.37 | 9,893 | 92 | 4.093 | 41.254 | 23.0 | 740.0 | 9,500 |
| 64 | | 310.17 | 11,698 | 82 | 4.839 | 48.781 | 20.5 | 875.0 | 13,000 |
| 66 | | 371.69 | 14,018 | 75 | 5.798 | 58.455 | 18.7 | 1,056.0 | 15,000 |
| 72 | | 443.12 | 16,712 | 70 | 6.913 | 69.689 | 17.5 | 1,250.0 | 17,000 |
| 80 | | 528.21 | 19,921 | 61 | 8.240 | 83.070 | 15.2 | 1,490.0 | 20,000 |

[a] Made by Swain Turbine and Manufacturing Company, Lowell, Mass. This was one of the earliest turbines of the American type. The original design followed the Francis center-vent wheel, but the buckets were curved both axially and radially and extended downward from inlet ring. Outside cylinder gate.

[b] Made by Wm. Dolan & Co., Logansport, Ind. Outside cylinder-gate turbine and deep bulging buckets.

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*Rating tables for cylinder-gate turbines*—Continued

DOLAN'S IMPROVED LITTLE GIANT.[a]

[1898 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 6 | | 4.13 | 162 | 816 | 0.064 | 0.676 | 204.0 | 12 | 215 |
| 8 | | 7.70 | 289 | 618 | .120 | 1.205 | 154.5 | 22 | 305 |
| 10 | | 12.18 | 464 | 490 | .190 | 1.935 | 122.5 | 35 | 410 |
| 12 | | 19.54 | 723 | 397 | .305 | 3.015 | 99.2 | 54 | 615 |
| 15 | | 25.24 | 957 | 345 | .394 | 3.991 | 86.2 | 72 | 895 |
| 18 | | 30.91 | 1,168 | 282 | .482 | 4.871 | 70.5 | 87 | 1,250 |
| 20 | | 43.69 | 1,653 | 246 | .682 | 6.893 | 61.5 | 124 | 1,540 |
| 23 | | 59.92 | 2,259 | 214 | .935 | 9.420 | 53.5 | 169 | 2,170 |
| 27 | | 80.16 | 3,029 | 187 | 1.250 | 12.631 | 46.8 | 225 | 3,150 |
| 31 | | 100.45 | 3,925 | 160 | 1.567 | 16.367 | 40.0 | 293 | 3,600 |
| 36 | | 130.11 | 5,097 | 141 | 2.030 | 21.254 | 35.2 | 380 | 5,500 |
| 40 | | 161.07 | 6,297 | 122 | 2.513 | 26.258 | 30.5 | 470 | 7,100 |
| 44 | | 197.79 | 7,730 | 112 | 3.085 | 32.234 | 28.0 | 584 | 8,000 |
| 48 | | 241.50 | 9,538 | 104 | 3.767 | 39.773 | 26.0 | 714 | 9,200 |
| 54 | | 295.58 | 11,555 | 92 | 4.611 | 48.184 | 23.0 | 866 | 12,400 |
| 60 | | 364.55 | 14,751 | 80 | 5.687 | 61.512 | 20.0 | 1,104 | 17,000 |
| 66 | | 435.33 | 17,616 | 77 | 6.791 | 73.459 | 19.2 | 1,322 | 23,000 |
| 18 | Special | 37.09 | 1,403 | 279 | 0.579 | 5.850 | 69.7 | ..... | ..... |
| 21 | do | 51.59 | 1,952 | 243 | .805 | 8.140 | 60.7 | ..... | ..... |
| 24 | do | 69.46 | 2,618 | 211 | 1.084 | 10.917 | 52.7 | ..... | ..... |
| 28 | do | 91.82 | 3,469 | 184 | 1.433 | 14.466 | 46.0 | ..... | ..... |
| 32 | do | 115.48 | 4,514 | 158 | 1.801 | 18.823 | 39.5 | ..... | ..... |
| 38 | do | 146.45 | 5,739 | 138 | 2.285 | 23.932 | 34.5 | ..... | ..... |
| 42 | do | 179.96 | 7,033 | 119 | 2.807 | 29.328 | 29.7 | ..... | ..... |
| 46 | do | 222.09 | 8,672 | 110 | 3.465 | 36.162 | 27.5 | ..... | ..... |
| 50 | do | 264.70 | 10,454 | 102 | 4.129 | 43.593 | 25.5 | ..... | ..... |
| 56 | do | 345.23 | 13,495 | 91 | 5.386 | 56.274 | 22.7 | ..... | ..... |
| 62 | do | 399.96 | 16,183 | 78 | 6.239 | 67.483 | 19.5 | ..... | ..... |
| 68 | do | 513.21 | 20,766 | 75 | 8.006 | 86.594 | 18.7 | ..... | ..... |

[a] Made by Wm. Dolan & Co., Logansport, Ind. Outside cylinder-gate turbine and deep bulging buckets.

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*Rating tables for cylinder-gate turbines*—Continued.

HUNT STANDARD, NEW PATTERN.[a]

[1897 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 9 | | 6.33 | 254 | 516 | 0.099 | 1.059 | 129.0 | 19 | |
| 12 | No. 2 | 9.41 | 374 | 402 | .147 | 1.560 | 100.5 | 28 | |
| 12 | No. 1 | 12.66 | 508 | 402 | .197 | 2.118 | 100.5 | 38 | |
| 15 | | 18.99 | 762 | 337 | .296 | 3.178 | 82.2 | 57 | |
| 18 | | 29.52 | 1,189 | 276 | .460 | 4.958 | 69.0 | 89 | |
| 21 | | 41.25 | 1,656 | 242 | .644 | 6.906 | 60.5 | 124 | |
| 24 | | 52.99 | 2,124 | 209 | .827 | 8.857 | 52.2 | 159 | |
| 27 | | 66.15 | 2,672 | 188 | 1.032 | 11.142 | 47.0 | 200 | |
| 30 | | 79.32 | 3,180 | 166 | 1.237 | 13.261 | 41.5 | 238 | |
| 33 | | 97.15 | 3,891 | 153 | 1.516 | 16.225 | 38.2 | 292 | |
| 36 | | 114.99 | 4,609 | 139 | 1.794 | 19.220 | 34.7 | 345 | |
| 39 | | 134.54 | 5,397 | 129 | 2.099 | 22.505 | 32.2 | 404 | |
| 42 | | 154.08 | 6,176 | 118 | 2.404 | 25.754 | 29.5 | 462 | |
| 45 | | 166.84 | 6,760 | 111 | 2.603 | 28.189 | 27.7 | 506 | |
| 48 | | 178.68 | 7,348 | 103 | 2.787 | 30.641 | 25.7 | 550 | |
| 51 | | 210.74 | 8,617 | 98 | 3.288 | 35.933 | 24.5 | 645 | |
| 54 | | 246.66 | 9,886 | 92 | 3.848 | 41.224 | 23.0 | 740 | |
| 60 | | 310.66 | 12,452 | 83 | 4.846 | 51.925 | 20.7 | 932 | |
| 66 | | 344.99 | 13,828 | 76 | 5.382 | 57.663 | 19.0 | 1,035 | |
| 72 | | 383.32 | 15,364 | 69 | 5.980 | 64.068 | 17.2 | 1,150 | |

HERCULES.[b]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 9 | | 8.04 | 333 | 517 | 0.125 | 1.389 | 129.2 | 24.8 | |
| 12 | | 13.84 | 573 | 388 | .216 | 2.389 | 97.0 | 42.9 | |
| 15 | | 22.35 | 925 | 310 | .349 | 3.857 | 77.5 | 69.2 | |
| 18 | | 31.19 | 1,291 | 259 | .486 | 5.383 | 64.7 | 96.6 | |
| 21 | | 43.92 | 1,818 | 222 | .685 | 7.581 | 55.5 | 136.0 | |
| 24 | | 54.24 | 2,245 | 194 | .846 | 9.362 | 48.5 | 168.0 | |
| 27 | | 72.33 | 2,994 | 172 | 1.130 | 12.485 | 43.0 | 224.0 | |
| 30 | | 85.57 | 3,542 | 155 | 1.334 | 14.770 | 38.7 | 265.0 | |
| 33 | | 108.19 | 4,478 | 141 | 1.688 | 18.673 | 35.2 | 335.0 | |
| 36 | | 122.39 | 5,066 | 129 | 1.909 | 21.125 | 32.2 | 379.0 | |
| 39 | | 150.49 | 6,229 | 120 | 2.348 | 25.975 | 30.0 | 466.0 | |
| 42 | | 179.22 | 7,418 | 111 | 2.796 | 30.930 | 27.7 | 555.0 | |
| 45 | | 201.18 | 8,327 | 103 | 3.184 | 34.724 | 25.7 | 623.0 | |
| 48 | | 221.86 | 9,183 | 97 | 3.461 | 38.293 | 24.2 | 687.0 | |
| 51 | | 250.59 | 10,372 | 91 | 3.909 | 43.251 | 22.7 | 776.0 | |
| 54 | | 289.68 | 11,990 | 86 | 4.519 | 49.660 | 21.5 | 897.0 | |
| 57 | | 312.92 | 12,952 | 82 | 4.882 | 54.010 | 20.5 | 969.0 | |
| 60 | | 346.84 | 14,356 | 78 | 5.411 | 59.864 | 19.5 | 1,074.0 | |

[a] Made by Rodney Hunt Machine Company, Orange, Mass. This wheel has deep bucket inlets and double-curved bulging buckets. An inside cylinder gate is used with a garniture to conform with the vena contracta.

[b] Made by Holyoke Machine Company, Holyoke, Mass. A turbine of American type, with deep, double-curved, bulging buckets and inside cylinder gate. The runner formerly had rows of rib plates forming partial division plates to guide the water through the wheel.

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*Rating tables for cylinder-gate turbines*—Continued.

McCORMICK.[a]

[1894 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 9 | | 8.8 | 365 | 531 | 0.137 | 1.522 | 132.7 | | |
| 12 | | 15.4 | 635 | 398 | .240 | 2.648 | 99.5 | | |
| 15 | | 24.5 | 1,013 | 319 | .382 | 4.224 | 79.7 | | |
| 18 | | 35.8 | 1,482 | 257 | .558 | 6.180 | 64.2 | | |
| 21 | | 50.7 | 2,096 | 245 | .791 | 8.740 | 61.2 | | |
| 24 | | 66.9 | 2,768 | 202 | 1.044 | 11.542 | 50.5 | | |
| 27 | | 84.7 | 3,505 | 189 | 1.321 | 14.616 | 47.2 | | |
| 30 | | 102.1 | 4,223 | 167 | 1.593 | 17.610 | 41.7 | | |
| 33 | | 124.9 | 5,166 | 145 | 1.948 | 21.542 | 36.2 | | |
| 36 | | 143.4 | 5,931 | 142 | 2.237 | 24.732 | 35.5 | | |
| 39 | | 168.6 | 6,972 | 124 | 2.630 | 29.073 | 31.0 | | |
| 42 | | 207.0 | 8,561 | 120 | 3.229 | 35.699 | 30.0 | | |
| 45 | | 220.4 | 9,116 | 109 | 3.438 | 38.014 | 27.2 | | |
| 48 | | 248.6 | 10,284 | 98 | 3.878 | 42.884 | 24.5 | | |
| 51 | | 283.1 | 11,709 | 99 | 4.416 | 48.826 | 24.7 | | |
| 54 | | 333.3 | 13,786 | 91 | 5.199 | 57.488 | 22.7 | | |
| 57 | | 374.0 | 15,467 | 89 | 5.834 | 64.497 | 22.2 | | |
| 60 | | 470.1 | 19,447 | 82 | 7.334 | 81.094 | 20.5 | | |
| 66 | | 568.9 | 23,530 | 75 | 8.875 | 98.120 | 18.7 | | |
| 72 | | 716.0 | 29,614 | 74 | 11.170 | 123.490 | 18.5 | | |

McCORMICK'S NEW ENGLAND.[b]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 9 | | 8.3 | 346 | 584 | 0.129 | 1.443 | 146.0 | | |
| 12 | | 14.4 | 595 | 477 | .225 | 1.600 | 119.2 | | |
| 15 | | 23.2 | 962 | 382 | .362 | 4.012 | 95.5 | | |
| 18 | | 32.3 | 1,342 | 308 | .504 | 4.596 | 77.0 | | |
| 21 | | 45.5 | 1,890 | 294 | .710 | 7.881 | 73.5 | | |
| 24 | | 56.3 | 2,334 | 242 | .878 | 9.733 | 60.5 | | |
| 27 | | 75.2 | 3,113 | 226 | 1.173 | 12.981 | 56.5 | | |
| 30 | | 89.0 | 3,683 | 200 | 1.388 | 15.358 | 50.0 | | |
| 33 | | 112.4 | 4,657 | 174 | 1.753 | 19.420 | 43.5 | | |
| 36 | | 127.2 | 5,268 | 170 | 1.984 | 21.968 | 42.5 | | |
| 39 | | 156.0 | 6,468 | 148 | 2.434 | 26.972 | 37.0 | | |
| 42 | | 186.3 | 7,714 | 144 | 2.906 | 32.176 | 36.0 | | |
| 45 | | 209.2 | 8,660 | 131 | 3.264 | 36.112 | 32.8 | | |
| 48 | | 230.7 | 9,550 | 117 | 3.699 | 39.824 | 29.2 | | |
| 51 | | 260.6 | 10,786 | 118 | 4.065 | 44.878 | 29.5 | | |
| 54 | | 301.2 | 12,469 | 109 | 4.699 | 45.453 | 27.2 | | |
| 57 | | 325.4 | 13,470 | 106 | 5.076 | 56.170 | 26.5 | | |
| 60 | | 360.7 | 14,930 | 98 | 5.627 | 62.278 | 24.5 | | |

[a] Made by S. Morgan Smith Company, York, Pa. A turbine of the American type, with deep ladle-shaped bucket outlets protruding below and outside of the guide ring and inside cylinder gate. The tables given are from the catalogue of the S. Morgan Smith Company. Nearly identical rating tables for McCormick turbines are furnished by J. & W. Jolly, Holyoke, Mass.; Rodney Hunt Machine Company, Orange, Mass., and Dubuque Turbine and Roller Mill Company, Dubuque, Iowa. The wheels of these three manufacturers are known, respectively, as the Smith-McCormick, the Hunt-McCormick, and the McCormick-Holyoke turbines.

[b] Made by Hanover Foundry and Machine Company, Hanover, Pa.

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*Rating tables for cylinder-gate turbines*—Continued.

TAYLOR SLEEVE GATE.[a]

[1902 list.]

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 15.... | A..... | 5.76 | 223 | 293 | 0.090 | 0.930 | 73.2 | ..... | ..... |
| 15.... | B..... | 8.04 | 333 | 293 | .125 | 1.389 | 73.2 | ..... | ..... |
| 15.... | C..... | 13.84 | 573 | 293 | .216 | 2.389 | 73.2 | ..... | ..... |
| 15.... | D..... | 22.35 | 925 | 293 | .349 | 3.857 | 73.2 | ..... | ..... |
| 15.... | E..... | 31.33 | 1,295 | 293 | .489 | 5.400 | 73.2 | ..... | ..... |
| 15.... | Standard... | 45.14 | 1,866 | 293 | .704 | 7.781 | 73.2 | ..... | ..... |
| 18.... | .....do..... | 64.51 | 2,667 | 250 | 1.006 | 11.121 | 62.5 | ..... | ..... |
| 21.... | .....do..... | 88.27 | 3,649 | 216 | 1.377 | 15.216 | 54.0 | ..... | ..... |
| 24.... | .....do..... | 113.75 | 4,704 | 185 | 1.775 | 19.616 | 46.2 | ..... | ..... |
| 27.... | .....do..... | 144.21 | 5,963 | 166 | 2.250 | 24.866 | 41.5 | ..... | ..... |
| 30.... | .....do..... | 182.07 | 7,530 | 149 | 2.840 | 31.400 | 37.2 | ..... | ..... |
| 33.... | .....do..... | 216.69 | 8,985 | 135 | 3.380 | 37.467 | 34.7 | ..... | ..... |
| 36.... | .....do..... | 254.31 | 10,518 | 125 | 3.967 | 43.860 | 31.2 | ..... | ..... |
| 39.... | .....do..... | 302.32 | 12,502 | 116 | 4.716 | 52.133 | 29.0 | ..... | ..... |
| 42.... | .....do..... | 352.80 | 14,586 | 107 | 5.504 | 60.824 | 26.7 | ..... | ..... |
| 45.... | .....do..... | 401.30 | 16,596 | 100 | 6.260 | 69.205 | 25.0 | ..... | ..... |
| 48.... | .....do. .... | 460.27 | 19,037 | 93 | 7.180 | 79.384 | 23.2 | ..... | ..... |
| 51.... | .....do..... | 533.13 | 21,678 | 86 | 8.317 | 90.397 | 21.5 | ..... | ..... |
| 54.... | .....do..... | 565.88 | 23,402 | 82 | 8.828 | 97.586 | 20.5 | ..... | ..... |
| 57.... | .....do..... | 652.11 | 26,971 | 78 | 10.173 | 112.469 | 19.5 | ..... | ..... |
| 60.... | .....do..... | 728.19 | 30,118 | 73 | 11.360 | 125.592 | 18.2 | ..... | ..... |
| 64.... | .....do..... | 816.24 | 33,759 | 68 | 12.733 | 140.775 | 17.0 | ..... | ..... |
| 68.... | .....do..... | 936.09 | 38,710 | 62 | 14.603 | 161.421 | 15.5 | ..... | ..... |

VICTOR TURBINE.[b]

[1897, 1900, and 1903 lists.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 12.... | Cylinder gate. | 12.29 | 678 | 406 | 0.192 | 2.827 | 101.5 | 60 | ..... |
| 15.... | .....do..... | 29.56 | 1,222 | 376 | .461 | 5.036 | 94.0 | 90 | ..... |
| 18.... | .....do..... | 42.59 | 1,761 | 314 | .664 | 7.343 | 78.5 | 130 | ..... |
| 21.... | .....do..... | 57.97 | 2,397 | 269 | .904 | 9.995 | 67.2 | 179 | ..... |
| 24.... | .....do..... | 75.71 | 3,131 | 235 | 1.181 | 13.056 | 58.7 | 231 | ..... |
| 27.... | .....do..... | 95.83 | 3,963 | 209 | 1.495 | 16.526 | 52.2 | 294 | ..... |
| 30.... | .....do..... | 118.31 | 4,893 | 188 | 1.846 | 20.404 | 47.0 | 365 | ..... |
| 33.... | .....do..... | 143.15 | 5,920 | 171 | 2.233 | 24.686 | 42.7 | 442 | ..... |
| 36.... | .....do..... | 170.36 | 7,046 | 156 | 2.658 | 29.382 | 39.0 | 520 | ..... |
| 39.... | .....do..... | 199.94 | 8,269 | 144 | 3.119 | 34.482 | 36.0 | 617 | ..... |
| 42.... | .....do..... | 231.88 | 9,590 | 134 | 3.617 | 39.990 | 33.5 | 717 | ..... |
| 45.... | .....do..... | 266.19 | 11,009 | 125 | 4.152 | 45.908 | 31.2 | 821 | ..... |
| 48.... | .....do..... | 302.87 | 12,526 | 116 | 4.725 | 52.233 | 29.0 | 927 | ..... |

[a] Made by John Williams Taylor, Atlanta, Ga. A turbine of recent design, having outside cylinder gate and very deep bucket inlet. The buckets bulge downward but do not extend outside of circumference of inlet ring. The guide chutes and buckets are divided into three compartments by partition plates.

[b] Made by Stillwell-Bierce and Smith-Vaile Company, Dayton, Ohio. The Victor turbine resembles the McCormick pattern. It has very deep bucket inlets, bulging ladle-shaped discharge, and inside cylinder gate. Small-size Victor turbines for high heads are built with register gate. The high-pressure turbine is a recent design (1903), and is tabled for heads of 70 to 675 feet.

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*Rating tables for cylinder-gate turbines*—Continued.

VICTOR TURBINE—Continued.

| Diameter of runner in inches. | Listed style or number. | Manufacturer's rating for a head of 16 feet. | | | Coefficients. | | | Vent in square inches. | Weight in pounds. |
|---|---|---|---|---|---|---|---|---|---|
| | | Horsepower. | Discharge in cubic feet per minute. | Revolutions per minute. | Power (=P). | Discharge (=F). | Speed (=N). | | |
| 51 | Cylinder gate | 341.91 | 14,141 | 107 | 5.334 | 58.968 | 26.7 | 1,055 | |
| 54 | do | 383.32 | 15,854 | 102 | 5.980 | 66.111 | 25.5 | 1,154 | |
| 57 | do | 427.09 | 17,664 | 97 | 6.663 | 73.659 | 24.2 | 1,318 | |
| 60 | do | 473.24 | 19,573 | 92 | 7.382 | 81.619 | 23.0 | 1,463 | |
| ( | Register gate | 4.05 | 160 | 814 | .063 | .667 | 203.5 | | |
| 8 | do | 5.76 | 223 | 616 | .099 | .930 | 154.0 | | |
| 10 | do | 10.07 | 397 | 488 | .157 | 1.665 | 122.0 | | |
| 12 | do | 15.19 | 579 | 395 | .237 | 2.414 | 98.8 | | |

VICTOR HIGH PRESSURE.[a b]

[1903 list.]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 14 | | 37 | 247 | 656 | 0.037 | 0.412 | 65.6 | | |
| 16 | | 50 | 332 | 574 | .050 | .553 | 57.4 | | |
| 18 | | 66 | 442 | 510 | .066 | .733 | 51.0 | | |
| 20 | | 82 | 542 | 459 | .082 | .903 | 45.9 | | |
| 22 | | 106 | 707 | 417 | .106 | 1.178 | 41.7 | | |
| 24 | | 128 | 850 | 383 | .128 | 1.417 | 38.3 | | |
| 26 | | 151 | 1,001 | 353 | .151 | 1.668 | 35.3 | | |
| 28 | | 173 | 1,147 | 328 | .173 | 1.912 | 32.8 | | |
| 30 | | 191 | 1,265 | 306 | .191 | 2.108 | 30.6 | | |
| 33 | | 228 | 1,512 | 278 | .228 | 2.520 | 27.8 | | |
| 36 | | 272 | 1,805 | 255 | .272 | 3.008 | 25.5 | | |
| 39 | | 303 | 2,005 | 235 | .303 | 3.342 | 23.5 | | |
| 42 | | 343 | 2,277 | 219 | .343 | 3.795 | 21.9 | | |
| 45 | | 387 | 2,563 | 204 | .387 | 4.272 | 20.4 | | |
| 48 | | 426 | 2,820 | 191 | .426 | 4.700 | 19.1 | | |
| 51 | | 462 | 3,063 | 180 | .462 | 5.105 | 18.0 | | |
| 54 | | 504 | 3,340 | 170 | .504 | 5.567 | 17.0 | | |
| 57 | | 544 | 3,605 | 161 | .544 | 6.008 | 16.0 | | |
| 60 | | 590 | 3,907 | 153 | .590 | 6.512 | 15.3 | | |
| 63 | | 619 | 4,100 | 146 | .619 | 6.833 | 14.6 | | |
| 66 | | 680 | 4,505 | 139 | .680 | 7.508 | 13.9 | | |
| 69 | | 742 | 4,910 | 133 | .742 | 8.183 | 13.3 | | |
| 72 | | 799 | 5,290 | 127 | .799 | 8.817 | 12.7 | | |

[a] Made by Stillwell-Bierce and Smith-Valle Company, Dayton, Ohio. The Victor turbine resembles the McCormick pattern. It has very deep bucket inlets, bulging ladle-shaped discharge, and inside cylinder gate. Small-size Victor turbines for high heads are built with register gate. The high pressure turbine is a recent design (1903), and is tabled for heads of 70 to 675 feet.

[b] Table gives maker's rating for head of 100 feet.

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## LITERATURE.

### HISTORICAL.

APPLETON'S CYCLOPEDIA OF APPLIED MECHANICS. Modern mechanism, vol. 3, pp. 891–901.

Description of the development of the turbine.

FANNING, J. T. History of the development of American water powers. Rept. 22d Ann. Meeting, Am. Paper and Pulp Assoc., 1898, pp. 16–24.

FAIRBAIRN, WILLIAM. Machinery and millwork.

Description of the undershot water wheel, pp. 145–150; description of earlier types of turbines, pp. 151–173.

FRANCIS, JAMES B. Lowell hydraulic experiments, pp. 1–70.

Description and tests of Boyden-Fourneyron Tremont turbines; also the Boyden-Francis "center-vent" turbine, in which the flow was radially inward.

FRANCIS, JAMES. Water power in New England. Eng. Rec., vol. 33, 1896, pp. 418–419.

FRANKLIN INSTITUTE. The Koechlin turbine. Jour. Franklin Inst., 3d ser., vol. 20, 1850, pp. 189–191.

Report of experiments made by members of the institute at the request of Emile Geyelin, who introduced the Koechlin turbine at Dupont's powder mill.

GEYELIN, EMILE. Experiments upon two hydraulic motors, showing the comparative power between an overshot wheel and a Jonval turbine made for Troy, N. Y. Jour. Franklin Inst., 3d ser., vol. 22, 1851, pp. 418–419.

GEYELIN, EMILE. First pair of horizontal turbines ever built working on a common axis. Proc. Eng. Club, Philadelphia, vol. 12, 1895, pp. 213–214.

GLYNN, JOSEPH. Power of water, pp. 39–97.

KNIGHT'S MECHANICAL DICTIONARY, vol. 3, water wheel, p. 2746; turbine, pp. 2656–2658.

MORIN, ARTHUR. [Experiments on water wheels having a vertical axis, called turbines], 1838. Translated by Ellwood Morris in Jour. Franklin Inst., 3d ser., vol. 6, 1843, pp. 234–246, 289–302, 370–377.

MORRIS, ELLWOOD. Remarks on reaction water wheels used in the United States and on the turbine of M. Fourneyron. Jour. Franklin Inst., 3d ser., vol. 4, 1842, pp. 219–227 289–304.

MORRIS, ELLWOOD. [Translation.] See Morin, Arthur.

MORRIS, ELLWOOD. Experiments on the useful effect of turbines in the United States. Jour. Franklin Inst., 3d ser., vol. 6, 1843, pp. 377–384.

RICE, A. C. Notes on the history of turbine development in America. Eng. News, vol. 48, 1902, pp. 208–209.

TYLER, W. W. The evolution of the American type of water wheel. Jour. Western Soc. Eng., Chicago, vol. 3, 1898, pp. 879–901.

WEBBER, SAMUEL. Ancient and modern water wheels. Eng. Mag., vol. 1, 1891, pp. 324–331.

WEBBER, SAMUEL. Water power, its generation and transmission. Trans. Am. Soc. Mech. Eng., vol. 17, 1896, pp. 41–57.

WHITELAW, JAMES. Observations on Mr. Ellwood Morris's remarks on water wheels. Jour. Franklin Inst., 3d ser., vol. 8, 1844, pp. 73–80.

### DESCRIPTIVE.

BJÖRLING, PHILIP R. Water or hydraulic motors, pp. 65–128.

CASSIER'S MAGAZINE, Niagara power number, vol. 8, 1895, pp. 173–384.

Complete description and drawings of turbines of Niagara Power Company.

PRASIL, FRANZ. Die turbinen und deren regulatoren, etc. Review of exhibits at the Geneva Exhibit in 1896. Schweizerische Bauzeitung, Nov.-Dec., 1896.

PRASIL, FRANZ. Turbine building and turbo-electric stations in Switzerland. Eng. Mag. pp. 245–256, 347–359.

An excellent review of recent European practice.

Digitized by Google

REICHTEL, PROF. E. Turbinenbau. Zeitschrift der Verein der Duetscher Ingenieurs, May 26, 1900.

Review of the art of turbine construction in Europe.

RICHARDS, CHARLES B. Report on machinery and apparatus adapted for general use in mechanical engineering. Paris Universal Exposition, 1889, turbines, pumps, and hydraulic motors. House Executive Doc., 51st Cong., 1st sess. 1889–90, vol. 40, pp. 154–180.

WAGENBACH, W. Neuere turbinen-Anlagen, Berlin, 1905.

Description of recent European practice.

See also elaborate works in German by Meissner, Rittinger, and Redtenbacher; also files of engineering periodicals containing descriptions of hydro-electric plants recently constructed.

### VERTICAL WATER WHEELS (OVERSHOT, UNDERSHOT, BREAST, ETC.).

BELLINGER, L. F. Chinese wheels. Eng. News, vol. 47, 1902, p. 494.

BJÖRLING, PHILIP R. Water or hydraulic motors, pp. 17–39, 54–64.

BOVEY, HENRY T. Treatise on hydraulics, 1901, pp. 416–472.

A mathematical discussion.

BRESSE-MAHAN. Hydraulic motors, 1869, pp. 9–65.

CHRISTIE, WILLIAM WALLACE. Some old-time water wheels. Eng. News, vol. 42, 1899, p. 394.

Description of a number of old vertical water wheels in northern New Jersey.

ENGINEERING NEWS. German designs of breast wheels. Eng. News, vol. 48, 1902, p. 436.

EVANS, OLIVER. Millwright and miller's guide, 1853.

Plans of wooden water wheels as constructed in first half of nineteenth century in America; also results of James Smeaton's tests of water wheels.

FRIZELL, J. P. The old-time water wheels of America. Trans. Am. Soc. Civ. Eng., vol. 28, 1893, pp. 237–249.

WEISBACH-DUBOIS. Mechanics of engineering, vol. 2, pp. 171–340.

Elaborate treatment, including theory, design, and construction of overshot, breast, Poncelet, and undershot water wheels as constructed in Germany and elsewhere.

WRIGHT, ALBERT E. Current wheels; their use in lifting water for irrigation. Bull. 146, Office of Experiment Stations, U. S. Department of Agriculture.

DES INGENIEURS TASCHENBUCH, 1902, part 1, pp. 767–781.

Latest and perhaps best discussion of design and construction of overshot and breast water wheels.

### TURBINES.

#### TURBINE DESIGN.

BUCHETTI. Les moteurs hydrauliques actuels, Paris, 1892.

BODMER, G. R. Hydraulic motors and turbines. Theory and design of reaction turbines, 1902, pp. 24–194.

Statement of mathematical principles and designs of vanes, guides, etc., for axial-, inward-, outward-, and parallel-flow turbines.

INNES, CHARLES H. Centrifugal pumps and turbines, pp. 35–72.

Contains theory and design of vanes of radial-flow reaction turbines.

MARKS, G. CROYDEN. Hydraulic power engineering, 1900, pp. 263–314.

A few pages devoted to simple examples of designing turbines for special cases. Little mathematics.

MUELLER. Die Francis Turbinen, Hannover, 1901.

MEISSNER. Die Hydraulik und hydraulisclien Motoren, Jena, 1878.

Digitized by Google

WOOD, DE VOLSON. Theory of turbines.

Design of guides and vanes, based on late theory, including centrifugal force and friction effects.

*Anonymous.*

DES INGENIEURS TASCHENBUCH, 1902, part 1, pp. 781–808.

Practical formulas and designs for Jonval and inward downward-flow turbines (Francis type).

AMERICAN TYPE OF TURBINE.

BARBER, T. Notes on the development of water power. Engineering Society, School of Practical Science, Toronto, No. 13, pp. 189–200.

Practical notes on selection and use of turbines.

BELL, LOUIS. Electric power transmission, 3d edition, pp. 324–344.

BODMER, G. R. Hydraulic motors and turbines, 1902, pp. 466–499.

FRIZELL, J. P. Water power, pp. 266–305.

Discussion of discharge relations and various American designs.

THURSO, J. W. Modern turbine practice and water-power plants, New York, 1905.

THURSTON, R. H. The systematic testing of turbine water wheels in the United States. Trans. Am. Soc. Mech. Eng., vol. 8, 1887, pp. 359–420.

WEBBER, SAMUEL. Efficiency of turbines as affected by form of gate. Trans. Am. Soc. Mech. Eng., vol. 3, 1882, pp. 84–86.

WOOD, DE VOLSON. Theory of turbines, pp. 67–149.

Analysis of Francis (J. B.) and Holyoke (Mass.) tests of Boyden and Swain wheels.

See also catalogues of American turbine builders, and files of engineering journals containing descriptions of hydro-electrical plants.

MATHEMATICAL THEORY OF TURBINES.

ATTERBERG, GUSTAF. Theory for turbine water wheels. Van Nostrand's Eng. Mag., vol. 26, 1882, pp. 138–146, 230–238.

BOVEY, HENRY T. Treatise on hydraulics, 1901, pp. 490–538.

A mathematical discussion of conditions governing efficiency in inward-, outward-, downward-, and mixed-flow turbines.

BRESSE-MAHAN. Hydraulic motors, 1869, pp. 66–110.

Discussion of Fourneyron turbines, with remarks on tub wheels and on the Girard type impulse wheel, which is termed a "reaction" turbine and compared to a Fourneyron turbine with one guide chute.

CHURCH, I. P. Hydraulic motors, New York, 1905.

CHURCH, I. P. The alleged "remarkable error in the theory of the turbine water wheel." Jour. Franklin Inst., 3d ser., vol. 87, 1884, pp. 333–340.

Criticism of paper presented by J. P. Frizell in Jour. Franklin Inst., 3d ser., vol. 86, 1883, pp. 92–96.

CHURCH, I. P. Turbines. Jour. Franklin Inst., 3d ser., vol. 93 (whole-number vol. 123), 1887, pp. 323–331, 379–387.

ESCHER, R. Über Niederdrück Turbinen mit gesteigerter Umdrehungszahl. Schweizer. Bauzeit., Jan. 8, 1898.

A mathematical discussion of bucket curves for low-head turbines of high rotative speed.

FOX, WILLIAM. Graphics of water wheels. Stevens Indicator, vol. 15, 1898, pp. 374–387.

Discussion of turbine theory and design by graphical methods.

FRIZELL, J. P. A remarkable error in the common theory of the turbine water wheel. Jour. Franklin Inst., 3d ser., vol. 86, 1883, pp. 92–96.

FRIZELL, J. P. An inquiry as to a more perfect form of water wheel, Boston, 1897.

Valuable discussion of possibility of obviating defects in present types of turbines.

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FRIZELL, J. P. The discharge of turbine water wheels. Jour. Franklin Inst., 3d ser., vol. 88, 1884, pp. 29–34.

FRIZELL, J. P. Note on the discharge of turbine water wheels. Jour. Franklin Inst., 3d ser., vol. 94 (whole-number vol. 124), 1887, pp. 67–71.

HERMANN. Graphische Theorie der Turbinen und Kreiselpumpen, Berlin, 1887.

SPEIDEL-WAGENBACH. Über Francis-Turbinen-Schaufelung. Zeitschrift des Vereins der Deutschen Ingenieure, Aug. 21, 1897.

A recent mathematical discussion of the Francis turbine as used in Germany, with graphical methods of design.

THURSTON, R. H. The theory of turbines. Jour. Franklin Inst., 3d ser., vol. 86, 1883, pp. 440–459; vol. 87, 1884, pp. 6–19.

TROWBRIDGE, W. P. Turbine wheels. Van Nostrand Science Series, No. 44.

VIGREUX, Ch. Turbines, Paris, 1889, pp. 1–140.

Treats chiefly of inward-flow turbines.

WEISBACH-DUBOIS. Mechanics of Engineering, vol. 2, pp. 341–536.

Discussion and theory of rouets and tub wheels; the evolution of the Jonval turbine by addition of guides; theory of inward-, outward-, and parallel-flow turbines; Fontaine, Thomson, Whitelaw, and Fourneyron turbines; various screw turbines; Danaïdes, Barker's mill, and other novel forms. Chiefly of historical interest.

WOOD, DE VOLSON. Hydraulic reaction motors. Trans. Am. Soc. Mech. Eng., vol. 14, 1893, pp. 266–309.

WOOD, DE VOLSON. Theory of turbines, pp. 1–66.

Mathematical discussion leading to practical formulas for initial and terminal angles and other conditions of best efficiency of inward- and outward-flow turbines, etc.

WOOD, DE VOLSON. Turbines. Jour. Franklin Inst., 3d ser., vol. 87, 1884, pp. 412–427.

WOODBRIDGE, J. LESTER. Turbines. Jour. Franklin Inst., 3d ser., vol. 92 (whole number vol. 122), 1886, pp. 351–365, 438–448.

ZUENER. Theorie der Turbinen. Leipsic, 1899.

TURBINE GOVERNING.

BELL, LOUIS. Electric power transmission, 3d edition, Regulation of water wheels, pp. 345–360.

CASSEL, ELMER F. Commercial requirements of water power governing. Eng. Mag., vol. 19, 1900, pp. 841–846.

GARRATT, A. V. Elements of design favorable to speed regulation in plants driven by water power. Eng. News, vol. 42, 1899, pp. 51–53, 139.

Discussion by John Sturgess.

HARE, W. A. Problem of speed regulation in power plants. Rept. Eng. Assoc., School of Practical Science, Toronto, No. 13, pp. 37–75.

INNES, CHARLES H. Centrifugal pumps and turbines, pp. 73–94.

The regulation of reaction turbines.

KNIGHT, SAMUEL N. Water-wheel regulation. Jour. of Elec., Nov., 1897.

PARKER, M. S. Governing of water power under variable loads. Trans. Am. Soc. Civ. Eng., vol. 37, pp. 17–23.

PERRINE, F. A. C. Regulation in long-distance power transmission by electricity. Eng News, vol. 44, 1900, pp. 161–162.

REPLOGLE, MARK A. Speed government in water-power plants. Jour. Franklin Inst., vol. 145, 1898, pp. 82–99.

WILLIAMS, HARVEY D. A new method of governing water wheels. Sibley Jour. of Eng., March, 1896.



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IMPULSE WATER WHEELS.

BJÖRLING, PHILIP R. Water or hydraulic motors, pp. 40–53.

Pelton water wheels.

BLAIRE, F. K. The efficiency of Pelton water wheels. Elec. World, Sept. 12, 1896.

Practical details as to setting and connections.

BODMER, G. R. Hydraulic motors and turbines. Theory, effect of centrifugal force, etc., 1902, pp. 211–275.

Relates to inward- and outward-flow wheels of the Girard type.

BOVEY, HENRY T. Treatise on hydraulics. Reaction and impulse turbines, 1901, pp. 482–490.

BUDAW, ARTHUR. Wirkungsweise des wassers in Laufrädern der Friestrahl turbinen. Zeitschrift der Oestrr. Ing. und Arch. Verein, May 30, 1902.

The action of water in free-jet turbines.

CAZIN-LIBBY. Discussion on impulse turbines. Eng. News, vol. 37, 1897, pp. 326–327, 395–396; vol. 38, 1897, pp. 74–75.

CHURCH, I. P. Hydraulic motors, pp. 62–82.

DOBLE, W. A. The tangential water wheel. Trans. Am. Inst. Min. Eng., vol. 29, 1899, pp. 852–894.

ENGINEERING NEWS. Tests of new impulse water wheel. Results of tests of Hug water wheel. Eng. News, vol. 40, 1898, p. 327.

ENGINEERING NEWS. The Pelton water wheel. Eng. News, vol. 27, 1892, p. 172.

ESCHER, RUDOLF. Ueber die Schaufelung des Löffelrader. Schweiz. Bauzeit., April 20, 1905.

Buckets of impulse wheels.

GROOT, B. F. Experiments and formula for the efficiency of tangential water wheels. Eng. News, vol. 52, 1904, p. 430.

HATT, W. KENDRICK. An efficiency surface for Pelton motor. Jour. Franklin Inst., vol. 143, 1897, pp. 455–461.

HENRY-LECONTE. An efficient high-pressure water-power plant. Eng. News, vol. 50, 1903, pp. 311–312.

HENRY, G. J., Jr. Some points in the design of buckets for impulse water wheels. Eng. News, vol. 50, 1903, pp. 322–324.

HITCHCOCK, E. A. Impulse water-wheel experiments. Theory and results of experiments at Ohio State University. Elec. World, June 5, 1897.

INNES, CHARLES H. Centrifugal pumps and turbines, pp. 101–111.

Gives theory and describes single-nozzle, outward radial-flow, impulse water wheel similar to Girard wheel.

KINGSFORD, R. T. A complete theory of impulse water wheels and its application to their design. Eng. News, vol. 40, 1898, pp. 37–39.

FRANKLIN INSTITUTE. The Pelton water wheel. Jour. Franklin Inst., vol. 140, 1895, pp. 161–197.

Report of the institute, through its committee on science and arts, on the invention of Lester A. Pelton.

RICHARDS, JOHN. Notes on a problem in water power. Trans. Am. Soc. Mech. Eng., vol. 13, 1892, pp. 331–336.

SMITH, HAMILTON, Jr. Water power with high pressures and wrought-iron water pipe. Trans. Am. Soc. Civ. Eng., vol. 13, 1884, pp. 15–31.

TRINKHAM, RALPH R. and KINGDON, JUSTIN T. Tests of impulse wheels at the University of Michigan. The Michigan Technic, Ann Arbor, 1906, pp. 26–102.

VIGREUX, CH. Turbines. Paris, 1899, pp. 141–154.

Discussion of rouets and Pelton wheels.

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# INDEX.


A.

Page.

Acknowledgments to those aiding ..... 38
Adams, S., & Son, turbine of ..... 101
Alcott, T. C., & Son, turbine of ..... 105
Alcott's High-Duty turbine, description of 105
rating table for ..... 105–106
Alexander, Bradley & Dunning, turbine of . 96
Allentown Foundry and Machine Works, turbine of ..... 112
American turbine, description of ..... 114
rating table for ..... 114
tests of ..... 32–33
American type turbine, bibliography of .... 128
comparison of European types and ..... 15
description of ..... 14–15
Appleton Mills, turbines for, efficiency of .... 23

B.

Balanced-gate turbine, description of ..... 105
rating table for ..... 105
Barber & Harris turbine, tests of ..... 25
Barker's mill, description of ..... 9
reaction in ..... 17
Bartley & Sons, turbine of ..... 111
Bartley Water-tight turbine, description of 111
rating table for ..... 111
Biobligraphy of turbine ..... 126–130
Birkenbine, P. M., experiments by ..... 24
Black River, N. Y., turbines on ..... 85–86
Bloomingdale turbine, description of ..... 98
rating table of ..... 98
Bodine-Jonval turbine, description of ..... 99
rating table of ..... 99
Bollinger turbine, tests of ..... 28
Booth Cotton Mills, Francis turbine at, figure showing ..... 13
Boyden, Uriah, experiments by ..... 21, 24
turbine of ..... 23
Bradway (C. P.) Machine Works, turbine of. 110
Bradway turbine, description of ..... 110
rating table for ..... 110
Breast wheels, description of ..... 8
Bucket, definition of ..... 9
evolution of ..... 15
Burnham Brothers, turbine of ..... 104
Burnham's New Improved Standard turbine, description of ..... 104
rating table for ..... 104

C.

Camden Horizontal turbine, description of. . 109
rating table for ..... 108
Camden Steel Double turbine, description of 109
rating table for ..... 109

Page.

Camden turbine, discharge by ..... 77–78
tests of ..... 108–109
Camden Water Wheel Works, turbine of ... 109
Camden Vertical turbine, rating table for ... 109
Canada turbine, description of ..... 111
rating table for ..... 111
Carley Helical wheel, description of ..... 96
rating table of ..... 96
Case, definition of ..... 9
Case National Improved turbine, description of. ..... 102
rating table for ..... 102
Case National turbines, tests of ..... 30, 31–32
Case Wheel and Mill Co., turbine of ..... 102
Centennial turbine tests, results of ..... 21, 24–30
Centrifugal force, application of ..... 19
Chase Improved Jonval turbine, description of ..... 100
rating table for ..... 100
Chase turbine, tests of ..... 29
Chase Turbine Manufacturing Co., turbine of 100
Chevres, Switzerland, power house at, section of, figure showing ..... 84
Christiana Machine Co. turbine of ..... 105
Chutes, definition of ..... 9
types of ..... 16–17
Cole Dominion turbine, description of ..... 110
rating table for ..... 110
Cope, E. T., & Sons turbine, tests of ..... 26
Craig, Ridgway & Son, turbine of ..... 26
Crocker turbines, descriptions of ..... 108
rating table for ..... 108
Current meters, comparison of turbines and. 77–78
Curtis, Gates, turbine of ..... 101
Cylinder-gate turbines, rating tables for ... 119–125

D.

Dayton Globe Iron Works Co., turbine of ... 114
Discharge, calculation of, tables for ..... 90–92
influence of head on ..... 81–82
influence of speed on ..... 80–81
figures showing ..... 81, 82, 83
measurement of, by turbine ..... 7, 76–82
reliability of ..... 77–78
variations in ..... 78–82
figures showing ..... 78, 81, 82
Discharge, power, and speed, tables of ..... 94–125
tables of, discussion of ..... 87–90
Dix, J. L. & S. B., turbines of ..... 99
Dix Improved Jonval turbine, description of. 99
rating table for ..... 99
Dolan, William, & Co., turbine of ..... 120–121
Dolan's Improved Little Giant turbine, description of ..... 121




Digitized by Google

Page.

Dolan's Improved Little Giant turbine, rating table for ... 121
Dolan's Little Giant turbine, description of ... 120
rating table for ... 120
Double Perfection turbine, description of ... 96
rating table for ... 96
Double turbines, description of ... 16
Dubuque Turbine and Roller Mill Co., turbine of ... 103, 123
Dynamometer, plate showing ... 14

E.

Eclipse Double turbine, description of ... 101
rating table for ... 101
Eclipse turbines, tests of ... 33
Efficiency, measure of ... 19–22
Ellis, T. G., tests by ... 24, 30
Elmer water wheel, description of ... 112
rating table for ... 112
Emerson, James, tests by ... 24, 30–36, 83
Eureka Improved turbine, description of ... 112
rating table for ... 112
European type turbines, comparison of American types and ... 15

F.

Flenniken turbine, description of ... 103
rating table for ... 103
Floats, definition of ... 9
Flow, measurement of, by turbine ... 7, 76–82
Flutter wheel, description of ... 8
Fourneyron turbines, description of ... 9–12
figure showing ... 11
plan of, figure showing ... 10
rating table for ... 94
sections of, figures showing ... 10, 12
Francis, J. B., experiments of ... 13, 21
work of ... 23, 24
Francis turbine, description of ... 13
figures showing ... 13
Fultonville Foundry Co., turbine of ... 106

G.

Gas engine, relative efficiency of turbine and, figure showing ... 23
Gates, definition of ... 9
types of ... 16–17
Gates-Curtis turbine, description of ... 101
rating table for ... 101
Genesee Valley Manufacturing Co., turbine of ... 99
Geneva, Switzerland, power house near, section at ... 85
power house near, section at, figure showing ... 84
use of horizontal shaft by ... 83
Geyelin Double Jonval turbine, description of ... 13
Geyelin turbines, tests of ... 27
Goldie & McCullough turbine, tests of ... 27
Gravity, operation of water wheels by ... 7, 8
Guides, definition of ... 9
types of ... 16–17

H.

Hanover Foundry and Machine Company, turbine of ... 123

Page.

Head, influence of, on discharge ... 81–82
influence of, on speed ... 85
variation in, devices for counteracting ... 85
figure illustrating ... 84
Helmer's Patent Rome turbine, description of ... 101
rating table for ... 101
Henschel, O., invention of Jonval turbine by 12
Hercules turbine, description of ... 122
discharge and diameter of, relations of ... 86–87
discharge coefficients of ... 79
figures showing ... 78
rating table for ... 122
speed of ... 80, 86
tests of ... 35–36, 60–68
figures showing ... 38, 39, 40
velocity of ... 19
Herschel, Clement, on American type turbines ... 15
testing flume designed by ... 24
Holyoke, Mass., testing flume at ... 24
tests at ... 30, 33–36
reliability of, as to discharge ... 77–78
water measurement at ... 76–77
Holyoke Machine Company, turbine of ... 122
Holyoke Water Power Compay, flume of ... 24, 37
flume of, dynamometer of, plate showing ... 14
section of, figure showing ... 37
tests by ... 24, 30, 36–76
Horizontal shafts, turbines on, plates showing ... 82
use of ... 83
Horsepower, calculation of, table for ... 92–94
definition of ... 19
development of, in turbines ... 19–22
Howd, S. B., invention of inward-flow turbine by ... 13
Howd-Francis turbine, description of ... 13, 14
Humphrey Machine Company, turbine of ... 104
Humphrey Standard IXL turbine, description of ... 104
rating table for ... 103
Humphrey Standard XLCR turbine, description of ... 104
rating table for ... 104
Hunt Standard turbine, description of ... 122
rating table for ... 122

I.

Impulse, principle of ... 18–19
principle of, figures showing ... 18
Impulse water wheels, bibliography of ... 130
Isle of Man, overshot wheel on ... 8

J.

John Tyler Improved turbine, description of ... 95
rating table for ... 95
Jolly, J. & W., turbine of ... 133
Jones, E. D., & Sons, turbine of ... 108
Jones Little Giant turbine, description of ... 97
rating table for ... 97
Jonval turbine, description of ... 12–13
rating tables for ... 98–100


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K.

Page.

Kinetic energy, operation of water wheels by ..... 7,8
Kingston Foundry and Machine Works, turbine of ..... 95
Knowlton & Dolan turbine, tests of ..... 25

L.

Leffel (James) & Co., turbine of ..... 118
Leffel Improved Samson turbine, description of ..... 118
rating table for ..... 119
Leffel-Samson turbines, discharge by ..... 77
discharge coefficients of ..... 80
tests of ..... 66–67
figure showing ..... 66–71
Leffel turbine, description of ..... 14, 16, 118
discharge by ..... 77
rating table for ..... 117–118
tests of ..... 31
Lesner turbine, tests of ..... 35
Lesner's Improved turbine, description of .. 106
rating table for ..... 106
Literature, list of ..... 126–130
Little Giant turbine, tests of ..... 14

M.

McCarthy & Doremus Manufacturing Co., turbine of ..... 98
McCormick, J. B., invention of turbines by. 14
McCormick Holyoke turbine, tests of ..... 44, 46, 51, 55, 59
McCormick turbines, description of ..... 123
discharge coefficients of ..... 79
rating table for ..... 123
tests of ..... 40–59
tests of, figures showing ..... 41, 42
*See also* Smith-McCormick; McCormick Holyoke.
McCormick's New England turbine, rating table for ..... 123
McElwain, H. S., & Co., turbines of ..... 94, 98
McElwain-Jonval turbine, description of ... 98
rating table of ..... 98
McElwain's Fourneyron turbine, description of ..... 94
rating table for ..... 94
Mechanical principles, explanation of ..... 17–19
Mechanicsville, N. Y., water measurement at ..... 77
Mixed-flow turbines, descriptions of ..... 13–15
Morin, Arthur, experiments by ..... 21, 22–23
Morris, Elwood, experiments by ..... 21, 23
Morris Canal, use of Barker's mill on ..... 9
Mosser, W. F., turbine of, tests of ..... 29
Motors, efficiency of, figure showing ..... 23
Munson Brothers, turbine of ..... 97

N.

National turbine, tests of ..... 29
New American turbine, description of ..... 114
discharge coefficients of ..... 80
rating table for ..... 115–116
tests of ..... 71–74
tests of, figure showing ..... 71
New Jersey, stream measurement in ..... 77
New York, stream measurement in ..... 77
use of Jonval turbines in ..... 13
Niagara Falls, N. Y., Fourneyron turbines at, figures showing ..... 11, 12
Noyes & Sons' turbine, tests of ..... 26

O.

Obenchain, Matthew and John, invention of turbine by ..... 14
Osgood, John, turbine of ..... 99
Osgood Improved Jonval turbine, description of ..... 99
rating table for ..... 99
Overshot wheels, description of ..... 8

P.

Parallel downward-flow turbines. *See* Jonval turbine.
Parker Brothers, invention of scroll case by. 14
Perfection Standard turbine, description of. 96
rating table for ..... 96
Philadelphia, turbine tests at ..... 21, 23–24
Pivot-gate turbines, rating table for ..... 108–119
Poole & Hunt, turbine of ..... 116
Poole & Hunt Leffel turbine, rating table for 116
Power, speed, and discharge, tables of .... 94–125
tables of, discussion of ..... 87–90

R.

Radial inward-flow turbine. *See* Francis turbine.
Radial outward-flow turbines. *See* Fourneyron turbine.
Reaction, principle of ..... 17–18
principle of, figure showing ..... 17
Reading Foundry Co., turbine of ..... 111
Register-gate turbines, rating tables for .. 101–107
Reynolds Champion turbine, tests of ..... 36
Reynolds Improved turbine, description of
rating table for ..... 95
Risdon, T. H., & Co., turbine of ..... 107
Risdon Cylinder and Register-gate turbines, description of ..... 107
rating table for ..... 107
Risdon turbine, efficiency of ..... 14
tests of ..... 25
Rochester turbine, description of ..... 119
rating table for ..... 119
Rochester Turbine Manufacturing Co., turbine of ..... 119
Rodney Hunt Machine Co., turbine of .... 122, 123
Rodney Hunt turbine, tests of ..... 27, 30
Rouet volante, description of ..... 8
Runner, definition of ..... 9
plate showing ..... 14
Ryther & Pringle, turbine of ..... 98

S.

Samson turbine, tests of ..... 66–71
tests of, figures showing ..... 66, 67
Sandy Hill Iron and Brass Works, turbine of ..... 98
Schiele turbine, description of ..... 14
figure showing ..... 14
Scope of paper ..... 7


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Page.

Scroll central-discharge turbines, descriptions of ..... 12,13
rating tables for ..... 95-97
Smeaton, James, experiments by ..... 21,22
Smith (S. Morgan) Co., turbines of ..... 113,123
Smith Improved Success turbine, description of ..... 113
rating table for ..... 113
Smith-McCormick turbine, speed and discharge of, relations of ..... 81
figure showing ..... 81
Smith-McCormick turbines, tests of ..... 43,45 47-50,52-54,55-57,58
Smith New Success turbine, description of . 113
rating table for ..... 114
Smith No. 2 Success turbine, diameter and discharge of, relations of ..... 86-87
Speed, calculation of, table for ..... 92-94
influence of, on discharge ..... 80-81
figure showing ..... 81,82,83
influence of head on ..... 85
Speed, discharge, and power, tables of .... 94-125
tables of, discussion of ..... 87-90
Square roots, table of ..... 90-92
Steam engine, relative efficiency of turbines and, figure showing ..... 23
Stillwell & Bierce Manufacturing Co., turbine of ..... 101
Stillwell-Bierce and Smith-Vaile Co., turbine of ..... 124,125
Stout, Mills & Temple turbine, tests of ..... 27
Sullivan Machine Co., turbines of ..... 95,102
Swain, A. M., testing flume of ..... 24
Swain turbine, description of ..... 120
rating table for ..... 120
tests of ..... 74,75-76
Swain Turbine and Manufacturing Co., turbine of ..... 120

T.

Tait turbine, tests of ..... 26
Tangential outward-flow turbines. *See* Barker's mill.
Taylor, J. W., turbine of ..... 124
Taylor sleeve-gate turbine, description of .. 124
rating table for ..... 124
Thompson vortex turbine, description of .. 14
Three-halves powers, table of ..... 92-94
Tide wheels, description of ..... 8
Trenton Falls, N. Y., Fourneyron turbine at 12
Trump Manufacturing Co., turbine of ..... 117
Trump Model turbine, description of ..... 117
rating table for ..... 117
Turbines, arrangement of, methods of ..... 82-84
bibliography of ..... 126-130
classes of, description of ..... 9-14
comparison of current meters and ..... 77-78
cost of ..... 85
definition of ..... 9
discharge and diameter of, relations of . 86-87
discharge measurements by ..... 77-78
variations in ..... 78-82
figures showing ..... 78,81,82
economy in size and number of, conditions governing ..... 85-87
efficiency of ..... 19-22

Page.

Turbines, efficiency of, figure showing ..... 23
figures showing ..... 11,14,82
horsepower of ..... 19-22
interference in ..... 22
lost energy in ..... 22
measurement of water by ..... 7,76-82
mechanical principles of ..... 17-19
parts of ..... 9
reliability of, as to discharge ..... 77-78
sections of, figures showing ..... 10,12,13,14
setting of, methods of ..... 82-84
testing of ..... 22-76
use of, as water meters ..... 7,76-82
Tyler, Benjamin, invention of turbine by .. 14
Tyler turbines, tests of ..... 28,30,34-35

U.

Undershot wheels, description of ..... 8
United States turbine, description of ..... 109
rating table for ..... 109
Unwin, W. C., on lost energy ..... 22

V.

Valley Iron Works Manufacturing Co., turbine of ..... 112
Vanes, definition of ..... 9
theory of ..... 18
figures showing ..... 18
Vertical shafts, use of ..... 82-83
Vertical water wheels, bibliography of ..... 127
descriptions of ..... 8
Victor High-pressure turbine, description of. 125
rating table for ..... 125
Victor turbine, description of ..... 124
rating table for ..... 124-125
tests of ..... 30,33-34
Vigreux, —, figure by ..... 22
Vulcan Iron Works, turbine of ..... 110

W.

Wait's Champion turbine, description of ... 98
rating table of ..... 98
Water, equivalent dimensions of ..... 20
measurement of ..... 7,76-82
waste of, in turbines ..... 22
weight of ..... 20
Water meters, use of turbines as ..... 7,76-82
Water rights, determination of ..... 7
Water-wheel design, essentials of ..... 16
Water wheels, classifications of ..... 7-8
efficiency of ..... 20-21
measurement of water by ..... 7,76-82
types of ..... 7-8
*See also* Turbines.
Water wheels, vertical, descriptions of ..... 8
Webber, Samuel, tests by ..... 24,30
Wetmore turbine, description of ..... 102
rating table for ..... 102
Whitelaw, James, development of Barker's mill by ..... 9
Wilson, J. C., & Co., turbine of ..... 97
Wolff turbine, tests of ..... 26

Y.

York turbine, tests of ..... 28


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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
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# GEOLOGY AND WATER RESOURCES

OF

# OWENS VALLEY, CALIFORNIA

BY

WILLIS T. LEE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1906

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# CONTENTS.


| | Page. |
|---|---|
| Introduction | 5 |
| Geography | 5 |
| Topography | 5 |
| General relations | 5 |
| Altitudes and slopes | 5 |
| Drainage | 6 |
| Owens River | 6 |
| Mono Lake drainage | 6 |
| Geology | 6 |
| Stratigraphy | 6 |
| Pre-Tertiary rocks | 6 |
| Tertiary sediments | 6 |
| Quaternary sediments | 7 |
| Volcanic features | 7 |
| Coso district | 7 |
| Big Pine district | 8 |
| Long Valley district | 8 |
| Hot springs | 8 |
| Mud geysers | 9 |
| Structural geology | 9 |
| History of the origin and development of the valley | 10 |
| General statement | 10 |
| Post-Tertiary uplift | 10 |
| Late Quaternary movements | 11 |
| Effects of Owens Valley earthquake | 12 |
| Underground waters | 12 |
| Artesian conditions | 12 |
| General statement | 12 |
| Well records | 13 |
| Inyo Development Company | 13 |
| Olanche | 13 |
| Dodge Brothers' well | 13 |
| Spear's well | 13 |
| Wrinkle's well | 13 |
| Roeper's well | 13 |
| Well near Black Rock Spring | 13 |
| Coe's wells | 13 |
| Bishop | 13 |
| Longley's well | 14 |
| Minor wells | 14 |
| Flowing area | 14 |
| Nonflowing area | 14 |
| Utilization of underground waters | 14 |
| Pumping plants | 14 |
| Power plants | 15 |


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Page.
Reservoir site..... 15
Effect of seismic disturbances..... 16
Structural materials..... 16
Building stone..... 16
Material for cement..... 16
Climate..... 17
Rainfall..... 17
Evaporation..... 19
Rate at Owens Lake..... 19
Rate at Bishop..... 20
Temperature..... 20
Undrained lakes as registers of climate..... 20
Owens Lake..... 20
Physical character..... 20
Chemical character..... 21
Mono Lake..... 23
Physical character..... 23
Chemical character..... 23
Discussion..... 23
Conclusion..... 24
Résumé..... 25
Index..... 27

## ILLUSTRATIONS.

Page.
PLATE I. Map of Owens Valley region..... 6
II. *A*, View of Owens Valley and the Sierra Nevada near Big Pine; *B*, Eastern face of Mount Whitney..... 8
III. *A*, Western face of the White Mountains near Alvord station; *B*, Granite bowlders of the alluvial slope at base of High Sierra near Big Pine.... 10
IV. View from "the Meadow" on the eastern slope of Mount Whitney..... 12
V. *A*, Panum Crater near Mono Lake; *B*, Crooked Creek near Long Valley dam site..... 16
VI. *A*, Crest of the High Sierra at Mammoth Mountain, *B*, Western lobe of Lyell Glacier..... 24

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# GEOLOGY AND WATER RESOURCES OF OWENS VALLEY, CALIFORNIA.

By WILLIS T. LEE.

## INTRODUCTION.

This report is the result of field studies made during the season of 1904 under the direction of Mr. N. H. Darton. The region considered includes Owens Valley, part of Mono Lake and Salt Wells valleys, and the slopes of the adjoining mountain ranges. A description of the geologic formations and structure is presented, with special reference to their bearing on the prospects for underground water. A general account of the surface waters also is given, with a discussion of the conditions likely to influence the storage of water in a region of recent seismic disturbances. Economic products in the nature of building materials are briefly described, and the effect of the present irrigation on the total water supply of Owens Valley is pointed out.

## GEOGRAPHY.

### TOPOGRAPHY.

*General relations.*—Owens Valley is located in east-central California, between the Sierra Nevada on the west and the White Mountains or Inyo Range on the east (see Pl. I), and includes the area drained by Owens River and its tributaries. It contains two smaller topographic depressions, Long and Round valleys. Owens Valley is the westernmost of the desiccated valleys of the Great Basin region and differs from the others in that it has an abundant water supply, derived mainly from the melting snows on the high mountains to the west. It is an undrained basin, the lowest part of which is occupied by a large salt lake.

*Altitudes and slopes.*—The floor to the valley has an average elevation of 3,700 feet, with a uniform gradient between Keeler and Bishop of 7 feet to the mile. The altitude, according to railway surveys, is 3,607 feet at Keeler, 3,661 feet at Lone Pine, 3,721 feet at Independence, and 4,107 feet at Bishop. North of Bishop the grade of the river is much steeper. Mono Lake is 55 miles from Bishop and the difference in elevation is 2,623 feet. The general altitude of the Sierra Nevada west of Owens Valley is about 12,500 feet, but several peaks of the range rise to elevations varying from 12,500 to nearly 15,000 feet; these are Mounts Whitney (see Pl. II, *B*), Williamson, Ritter, Lyell (see Pl. VI, *A*), and others. The rugged character of the range is illustrated in Pl. II, *A*. Between Owens Lake, the lowest point in the valley, and Mount Whitney, the highest peak of the Sierra Nevada, the difference in altitude is about 11,300 feet, but there are other places much nearer together where differences nearly as great occur.

The maximum elevation of the White Mountains is reached in White Mountain Peak, which is 11,321 feet high. To the south the average altitude is about 10,000 feet. The western side of the White Mountains, which faces Owens Valley, is a steep though regular slope, as shown in Pl. III, *B*, but it is much less deeply dissected by erosion than the eastern face of the Sierra Nevada. The Coso Mountains comprise the southern part of the White Mountains, but they are separated from the Mountains on the north by a low pass east of Owens Lake.



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## DRAINAGE.

*Owens River.*—The principal drainage in this region is into Owens River, a main stream with a large number of important tributaries entering mainly from the west, those from the east being intermittent. The waters of Owens River empty into Owens Lake, from which they escape only by evaporation. There is a heavy precipitation on the western side of Owens Valley, resulting from the great elevation of the Sierra Nevada. The moisture-laden winds from the west lose much of their moisture in passing over this high range, and as a consequence the rainfall is very light in the main part of Owens Valley and the districts farther east. From the headwaters of Owens River, at Mount Lyell, southward to Mount Whitney, numerous streams enter the valley from the Sierra Nevada, as shown in Pl. I. The largest of these are South Branch, Rock, Pine, Bishop, Coyote, Big Pine, Tinemaha, Taboose, Oak, Shepherd, and Lone Pine creeks. South of Mount Whitney the tributaries are smaller and intermittent, because of the small amount of snow on the summit of the range. Owing to the steepness of the mountain slopes on the west, the streams are torrential in character, flowing through deep, narrow gorges on the higher slopes and emerging lower down onto detrital cones which they have deposited. Some of the smaller streams sink in the detrital material and the larger ones reach the river with greatly diminished volume.

The present form of the Owens River system (see Pl. I) is due largely to the change of climate in recent geologic time. Throughout a part at least of Quaternary time Owens River flowed southward through Salt Wells Valley, and the portion of Owens Valley north of Bishop probably contained a flowing stream. During the changes toward greater aridity of climate which took place later, the water supply was cut off from the upper part of Owens River and one of its main tributaries was left as the head of the stream. At the time evaporation in the valley equaled or exceeded the inflow, that part of the river south of Owens Lake ceased to flow, and the tributaries from the White Mountains became dry from lack of sufficient rainfall, if, indeed, they ever had been permanent streams. The result is a river system of considerable size truncated at both ends and modified on the east side, with only its middle portion still active.

*Mono Lake drainage.*—There are several short mountain streams in the northern part of the district which empty into Mono Lake. Rush Creek, the largest of these, is a stream of considerable size. It derives its waters principally from melting snows high on the slopes of the Sierra Nevada near Mount Lyell. (See Pl. VI, *A*). Mono Lake is similar to Owens Lake both in its physical character and in the chemical composition of its waters. The two lakes are nearly the same in size, Mono having an area of about 85 square miles and Owens about 75 square miles. Both are located at the eastern base of the Sierra Nevada and, although about 125 miles apart, both derive their water supply from the vicinity of Mount Lyell. Mono Lake, however, lies at an elevation about 3,000 feet higher than Owens Lake. Neither lake has an outlet.

## GEOLOGY.

### STRATIGRAPHY.

#### PRE-TERTIARY ROCKS.

The older rocks appearing at the surface in the Owens Valley region consist of granite and more or less metamorphosed sediments, which are of Algonkian, Paleozoic, and Mesozoic age. The rocks are nearly impervious and, as they outcrop in a region of practically no rainfall, they probably do not contain much water. They form an impervious basin, however, for the water-bearing sands and gravels.

#### TERTIARY SEDIMENTS.

Deposits of sand, gravel, and clay of supposed Tertiary age occur at two localities in the Owens Valley region, one south of Owens Lake, between the Coso Mountains and the Sierra Nevada, and the other in the Waucobi embayment east of Alvord. In the area south of

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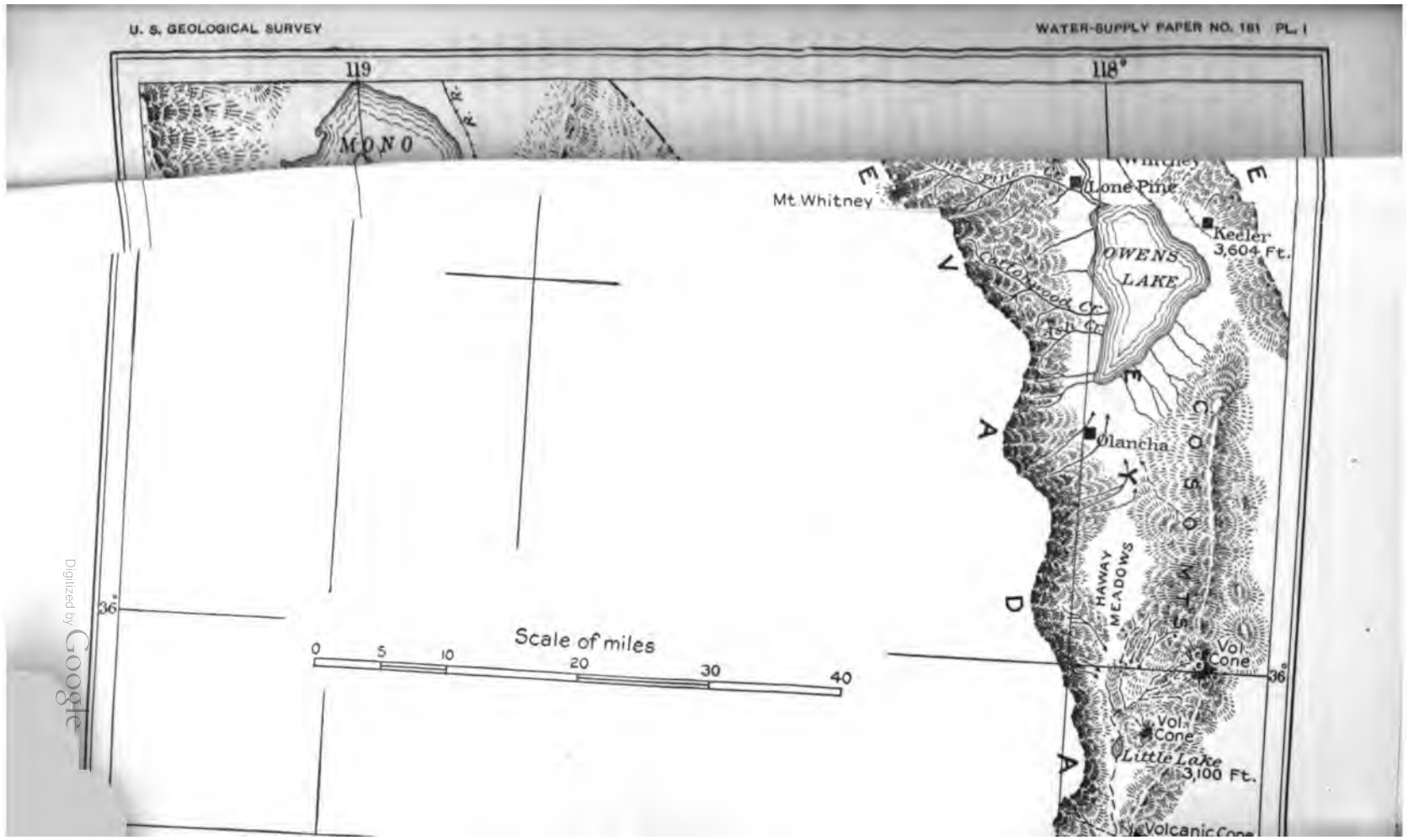


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Owens Lake the beds consist of partly consolidated deposits of sand, gravel, and clay, which attain a thickness of at least 1,500 feet and possibly more. These deposits have been referred to the Miocene by Fairbanks[a]. Near Haway Meadows, where at least 500 feet of this formation have been removed by erosion, a boring 1,028 feet deep did not pass through it.

The so-called Tertiary deposits occurring in the Waucobi embayment, east of Alvord, extend westward into Owens Valley, passing beneath the late Quaternary deposits of the valley floor. The strata consist of fine limy, sandy, and clayey beds with layers of conglomerate, the whole series being covered by wash brought down from the mountains. Near the mountains the deposits consist of coarse material which changes toward the valley to finer sediments. This formation has been described by Walcott[b] as a lake deposit of late Pliocene or Quaternary age, and the fresh-water shells, abundant in some beds, are considered by W. H. Dall[c] to be of Pleistocene age.

### QUATERNARY SEDIMENTS.

The Quaternary deposits in Owens Valley consist mainly of clay, volcanic ash, sand, and gravel laid down in successive layers which have a thickness of at least 465 feet beneath the lake level, as is shown by the record of the well at Keeler, near the eastern edge of Owens Lake. Material similar to that penetrated by the Keeler boring is found in terraces at an elevation of about 250 feet above the lake. These terraces, having the same elevation as the southern outlet of the valley, undoubtedly mark the level of the lake when it drained southward through Salt Wells Valley. At that time the lake probably extended northward as far as Bishop. In these terraces and in the material penetrated by the Keeler well fresh-water shells occur in considerable abundance. *Carinifex newberryi* Lea and *Odonta* sp. are the principal forms. These were identified by W. H. Dall, who believes that the species were denizens of Owens Lake and of other lakes extending over a wide range west of the Rockies. The desiccation of the lakes, with concentration of the alkaline salts in their waters, rendered them unsuitable for molluscan life, and the species were left only in streams and such lakes as remained fresh, where they are found at the present time in greatly diminished numbers.

Along the base of the mountains on either side of Owens Valley are detrital cones, which were brought down in late Quaternary time and are still in process of accumulation. Those at the base of the Sierra Nevada have a maximum elevation of about 2,000 feet above the river and are connected with each other, forming a continuous slope, while along the base of the White Mountains they are smaller and more isolated, and their outlines are better preserved. The material in the cones on the White Mountain side of the valley consists largely of detritus from sedimentary rocks; along the Sierra Nevada it is composed of granitic fragments. Many of the granite blocks are 10 to 15 feet in diameter, and some of them occur as far as 5 to 6 miles from the base of the mountains.

## VOLCANIC FEATURES.

The volcanic features of the Owens Valley region consist of crater cones, lava flows, hot springs, and mud geysers. The occurrence of the hot springs and mud geysers in this connection is probably significant. The volcanic deposits are found principally in three districts.

*Coso district.*—In the Coso Mountains, southeast of Owens Lake, extensive volcanic action has taken place and the effects of two distinct periods of eruption are apparent. The older flows have been deeply dissected by erosion, while the more recent lavas are not dissected, but still retain their original form. These lavas are mainly beyond the border of Owens Valley and no special study was made of them.

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[a] Fairbanks, H. F., Notes on the geology of eastern California: Am. Geologist, vol. 17, 1896, p. 67.
[b] Walcott, C. D., The post-Pliocene elevation of the Inyo Range: Jour. Geol., vol. 5, No. 4, 1897, pp. 340-348.
[c] Ibid, p. 342.

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*Big Pine district.*—There is a volcanic region near the center of Owens Valley, between Independence and Big Pine. The flows of basalt are evidently of very recent origin, overlying late Quaternary deposits and giving little evidence of weathering. Scoriaceous lava occurs in the irregular forms in which it cooled from the molten state, and numerous cinder cones contain craters which are more or less perfect. The lava once extended across the valley and for a considerable distance up the side of the White Mountains. In the floor of Owens Valley the lava sheet is now considerably eroded by the river and covered to some extent by alluvium. In the vicinity of Aberdeen the lavas occur near a group of granitic hills, which extend for some distance into the lower portion of the valley. (See Pl. I.) Flows of volcanic rock extend southward along the base of the Sierra Nevada to a point a few miles north of Independence. The extinct volcanic cone known as "Fish Spring Volcano" (see Pl. II, *A*) lies west of Aberdeen and is the largest and possibly the oldest volcanic cone in the region. It rises about 2,000 feet above Owens Valley and has a well-defined crater about 100 feet deep. At the base of the Sierra Nevada, west of Bishop, occur the northernmost cinder cones of this district.

*Long Valley district.*—The largest district of volcanic rocks within the area described in this report extends from the upper end of Round Valley to Mono Lake. In the southern part of the district the rock is dark colored and consists mainly of andesitic tuffs and breccias, which are well exposed in the bluffs of Owens River and Rock Creek, where they form bold, cavernous cliffs and rugged slopes. In some places large masses of material are almost wholly unconsolidated, while in others the tuff is solidified into resistant rock. The canyons which are cut through the andesite by Owens River and the smaller streams, such as Crooked Creek (Pl. V, *B*), are 200 to 300 feet deep, a fact indicative of considerable age. In that portion of the district which lies north of Long Valley the surface is more or less covered with volcanic products that are believed to be more recent than those farther south. They consist of obsidian, pumice, and unconsolidated ash, and are described in detail by Russell[a] in his paper on the Mono Lake region. Beds of ash and scoriaceous rock of this younger series were observed as far south as Casa Diablo. Panum Crater (Pl. V, *A*) is probably one of the best illustrations of the younger volcanic cones. Russell described this crater as follows: "The rough crags piled in the center of the bowl of lapilli are not of the nature of a cone of eruption, as might be supposed from our knowledge of Vesuvius and other similar volcanoes, but are ejections of a molten rock of the same character as the neighboring lava flows. They are in fact incipient coulées which were congealed before a definite flow in any direction had been established."

The central core of Panum Crater is completely surrounded by a sharp, V-shaped depression, the outer rim of which is a circular ridge composed of the volcanic cinders that form the outer part of the cone. The core rises to an elevation considerably higher than the cinder rim and is composed of scoria and black volcanic glass. The sides of the core are steep, craggy, and more or less broken, giving unmistakable evidence that it was thrust out en masse after the formation of the cinder rim and at a time when the material was in a semiplastic condition and yet resistant enough in general to hold the form given to it by the throat of the crater. Some of the blocks from the side of the core are elongated, some are warped or contorted, and many are scored and grooved on the sides, so that a differential motion is plainly indicated.

*Hot springs.*—Along the zone in which extinct volcanoes occur there is a series of hot springs. Although the temperature of the water in these springs is not necessarily due to volcanic heat, their close association with the old volcanoes suggests that the heat may be derived from that source. Several of the springs are grouped near the west end of Long Valley, where they form a stream of considerable size, known as Hot Creek. One of these springs is said to have been an active geyser until a few years ago, when the creek changed its course in such a way as to flow over the mouth of the geyser and destroy its intermittent action. Hot springs were observed in Owens Valley as far south as the group of volcanic cones between Independence and Big Pine.

[a] Russell, I. C., Quaternary history of Mono Valley, California: Eighth Ann. Rept. U. S. Geol. Survey, pt. 1, 1889, pp. 377–389.

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*A.* VIEW OF OWENS VALLEY AND THE SIERRA NEVADA NEAR BIG PINE.

Showing a volcanic cone ("Fish Spring" volcano) in the middle-ground and the Sierra Nevada in the distance.

*B.* EASTERN FACE OF MOUNT WHITNEY.

Cliffs in the center are about 3,000 feet high. Western slope of Sierra Nevada is seen in upper left-hand corner and a remnant of Tertiary slope at the right in the distance.

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*Mud geysers.*—There is a small mud geyser at Casa Diablo, near the west end of Long Valley, which is in continuous and violent action. At a number of places in its immediate vicinity the steam escapes in small quantities and for a considerable distance from the geyser the rock is more or less heated. This suggests either very recent volcanic activity or the beginning of future volcanic action. No vent showing signs of recent eruption was found near this place, and it is possible that the heat accompanies some initial rather than closing stage of volcanic activity. On the other hand, the heat may be due to friction or crushing caused by faulting. Casa Diablo is near the fault zone at the base of the Sierra Nevada, along which in other places there has been recent movement.

## STRUCTURAL GEOLOGY.

Owens Valley is a V-shaped trough, extending in a nearly straight line from Salt Wells Valley northward into Nevada east of Mono Lake. The western side of the trough is the granitic escarpment of the Sierra Nevada, a general view of which is given in Pl. II, *A*. The eastern side is the less steep face of the White Mountains (see Pl. III, *A*), composed principally of sedimentary rocks. The bottom of the trough is filled to an unknown depth with Tertiary and Quaternary deposits. From Owens Lake to Bishop, a distance of more than 70 miles, the trough, measured from crest to crest of the adjoining mountain ranges, is 12 to 25 miles wide. North of Bishop it is much wider.

The geologic structure of the Owens Valley region has been described in part by several geologists, mainly in connection with discussions of certain features of the Sierra Nevada. Briefly stated, it is assumed that this range is a large block of the earth's crust which in comparatively recent geologic time has been faulted and elevated at its eastern margin, with westward tilting of its surface. Although no conclusive proof has been presented that the eastern face or escarpment of the Sierra Nevada is due to faulting, confirmatory evidence has been discovered in a number of places. It has been shown by Gilbert [a] and Diller [b] that the western slope of the Sierra Nevada is a tilted peneplain and that the escarpment on the east is presumably due to faulting which accompanied the uplift and tilting of the great block. This faulting is indicated by the displacement of gravel deposits at the north end of the range as described by Diller,[b] also by similar movements of gravels near Mono Lake, of lava sheets north of Honey Lake, of gravels near Genoa, and of various rocks along the base of the Sierra Nevada in Owens Valley, as described by Russell,[c] Diller,[d] Lindgren,[e] and Whitney,[f] respectively.

Evidence of faulting and block tilting similar to that which affected the Sierra Nevada has been found in the White Mountains. Walcott[g] has shown that the strata of these mountains were contorted and strongly folded in comparatively early geologic time, but later the range, like the Sierra Nevada, moved as a large crust block. It has also been suggested by Walcott[h] that the steep eastern escarpment of the White Mountains may be due to faulting, while the westward inclination of the lake beds in the Waucobi embayment may be due to a tilting of the White Mountain block.

To these indications of faulting in the Owens Valley region may be added those observed by the writer. In the White Mountain face east of Lone Pine strata of Triassic age pass beneath the floor of Owens Valley, with a dip of about 50°. In the Alabama Hills west of Lone Pine the same formation is found in a shattered condition and associated with granitic rock in a manner clearly indicating displacement by faulting. Southwest of Bishop a small

[a] Gilbert, G. K., Science, vol. 1, 1883, pp. 194–195.
[b] Diller, J. S., Tertiary revolution in topography of Pacific coast: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 408, 432.
[c] Russell, I. C., Quaternary history of Mono Valley, California: Eighth Ann. Rep. U. S. Geol. Survey, pt. 1, 1889, p. 322.
[d] Diller, J. S., Geology of Lassen Peak district: Eighth Ann. Rept. U. S. Geol. Survey, pt. 1, 1889, p. 429.
[e] Lindgren, W., Age of the auriferous gravels of the Sierra Nevada: Jour. Geol., vol. 4, 1896, p. 902.
[f] Whitney, J. D., The Owens Valley earthquake: Overland Monthly, June, 1872.
[g] Walcott, C. D., The Appalachian type of folding in the White Mountain Range of Inyo County, Cal.: Am. Jour. Sci., 3d ser., vol. 49, 1895, pp. 169–174.
[h] Walcott, C. D., The post-Pleistocene elevation of the Inyo Range: Jour. Geol., vol. 5, 1897, pp. 340–348.

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exposure of marble occurs, apparently a displaced remnant of the extensive marble and limestone formation in the White Mountains, which passes beneath the floor of the valley at Independence, with a dip of 80°. There is evidence near Little Lake not only of displacement by faulting, but also of the rate at which displacement took place. At Little Lake, which has an altitude of 3,000 feet, the granite extends across the valley, and at Haway Meadows, at an altitude of 3,782 feet, a well bored to a depth of 1,028 feet was still in Tertiary sediments. The basin formed by the older rocks is therefore at least 246 feet deeper than the granite which forms the lowest part of its rim. How much deeper the basin is remains unknown. Its ascertained depth of 246 feet is clearly due to subsidence and not to erosion and indicates that the subsidence was more rapid than the down cutting of the river. The Tertiary strata at Haway Meadows dip westward at an angle of about 15° and terminate somewhat abruptly against the granite base of the Sierra Nevada, but it was not determined whether they were displaced there by a fault or otherwise.

## HISTORY OF THE ORIGIN AND DEVELOPMENT OF THE VALLEY.

### GENERAL STATEMENT.

As stated in the introduction, one of the purposes of the present investigation was to determine the prospects of successful water storage in this region of recent seismic disturbances. If Owens Valley has resulted from the formation and movements of crust blocks, accompanied by faulting, the time at which these movements occurred and the prospects of their recurrence must be considered in connection with a project for water storage in this valley. In case the crustal disturbances occurred only in ages long past, a stable condition of the surface might reasonably be expected; but, on the other hand, if movements have taken place recently an unstable condition may exist and earthquakes more or less disastrous to an irrigation system are to be expected. For these reasons the following brief history of the crustal movements in the Owens Valley region is given.

Disturbances of great magnitude are known to have occurred in both the Sierra Nevada and the White Mountain regions in pre-Tertiary time, resulting in the formation of mountain ranges. These movements obviously were too ancient to affect seriously the question here discussed and therefore need not be treated at length. Some time during the Tertiary period, however, a series of events began which do affect these questions. The peneplain of the western slope of the Sierra Nevada, first recognized by Gilbert,[a] has been further described by Diller,[b] who shows that the planation was probably accomplished during Miocene time. Gravels deposited upon this peneplain have been elevated, faulted, and tilted. Diller found them showing a vertical displacement of about 3,000 feet along the eastern face of the range at its north end. Similar displacements were found by Russell[c] near Mono Lake and by Turner[d] near Tower Peak. At the latter place gravel-covered plateaus occur near the summit of the range, close to the escarpment, which Turner explains as parts of the old peneplain raised to its present position after the deposition of the gravels. Parts of the peneplain are well preserved at Mammoth Mountain, and its relation to the eastern face of the Sierra Nevada is clearly shown in Pl. VI, *B*.

### POST-TERTIARY UPLIFT.

Since the time of King's survey,[e] observers of the Sierra Nevada region, with few exceptions, have assigned the main uplift to post-Tertiary time. Le Conte,[f] in a paper describing the geology of the western slope of the Sierra Nevada places the elevation of the moun-

[a] Gilbert, G. K., Science, vol. 1, 1883, pp. 194–195.
[b] Diller, J. S., Tertiary revolution in topography of Pacific coast: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 404–411.
[c] Russell, I. C., Quarternary history of Mono Valley, California: Eighth Ann. Rept. U. S. Geol. Survey, pt. 1, 1889, p. 322.
[d] Turner, H. W., Rocks of Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 442.
[e] King, Clarence, Rept. U. S. Geol. Explor. 40th Par., vol. 1, 1878, p. 744.
[f] Le Conte, Joseph, A post-Tertiary elevation of the Sierra Nevada, shown by the river beds: Am. Jour. Sci., 3d ser., vol. 32, 1886, pp. 167–181.

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*A*. WESTERN FACE OF THE WHITE MOUNTAINS NEAR ALVORD STATION.

Level valley floor in the foreground, and transition slope in the middle-ground. Photograph by C. D. Walcott.

*B*. GRANITE BOWLDERS OF THE ALLUVIAL SLOPE AT THE BASE OF THE SIERRA NEVADA, NEAR BIG PINE.

Photograph by C. D. Walcott.

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tains at the close of the Tertiary and suggests that their rise may have been coincident with an increasing aridity of climate in the Basin region and with the beginning of deposition of the Quaternary beds which occupy so large an area east of the range, including Owens Valley.

The assignment of the uplift to post-Tertiary time has recently been confirmed by certain observations of Turner.[a] From a study of the Tertiary gravels and lavas on the western face of the Sierra Nevada along Tuolumne River, he concludes that the Sierra block has been tilted to a notable extent since the close of the Tertiary period. He shows that the grade represented by the Neocene gravels averages 142 feet per mile, while the grade of the Tuolumne River is 92 feet per mile. He also points out that the Neocene stream was more mature than the present one and presumably flowed at a lower grade. He concludes: "Assuming that the Neocene Tuolumne had originally a grade as low as that of the modern stream, which is evidently yet a young stream, it is clear that the present grade of the Neocene channel must have been brought about by the differential uplift on the east, resulting in a tilting of the range westward."

It is probable that some of the phenomena observed by the present writer are to be explained by the post-Tertiary uplift. At certain places, especially in the vicinity of Mount Whitney, isolated and inclined table-lands terminated by nearly perpendicular cliffs, interrupt the continuity of the general slope of the mountains. Some of these table-lands have concave and others convex surfaces. One with a concave surface appears in the distance at the right in Pl. II, *B*. They are found in considerable numbers near Mount Whitney at an elevation of over 10,000 feet and they do not occur, so far as observed, below that elevation.

The rock floors of the gorges and cirques separating the table-lands give abundant evidence of glaciation. Polished and grooved surfaces and glacial lakes are numerous. Pl. IV is a view from "the meadow" on the Mount Whitney trail in one of these gorges. The cliff is the side of one of the table-lands. In this case the table is a concave surface of considerable extent and slopes steeply to the east.

The ancient slope represented by these table-lands is not in harmony with the general steep eastern face of the Sierra Nevada, and obviously it was formed before these mountains attained their present elevation. On the other hand, the deep gorges and wide cirques separating the table-lands give evidence of extensive erosion after the development of this ancient surface. They also indicate glaciation near the close of this period of erosion.

The succession of events, as inferred from the phenomena above described, is as follows: Previous to the last great uplift of the Sierra Nevada the land surface in the vicinity of Mount Whitney was one of low relief and gentle slopes. The uplift of the mountains, presumably at the close of the Tertiary, was followed by a period of rapid erosion of the now precipitous eastern face of the range. Near the close of this period the newly formed valleys (Pl. IV) were occupied by glaciers. How long they were thus occupied and whether the glaciers were major or minor factors in excavating the valleys are questions to which no answer is here offered.

### LATE QUATERNARY MOVEMENTS.

A movement of recent date in the White Mountains (Inyo Range) has been described by Walcott[b], who shows that a difference in elevation of about 3,000 feet has been effected within the range in comparatively recent geologic time. The lake beds of the Waucobi embayment, which are of late Pliocene or Quaternary age, have been tilted until at their eastern border they are 3,000 feet higher than at their western border in Owens Valley. Walcott suggests that the movement which tilted these beds occurred in late Quaternary time. This opinion is based mainly on the occurrence of a recently formed fault scarp, the truncation of spurs, and the presence of large springs along the line of the fault, and the formation of pools and bogs on land formerly crossed by wagon roads. Lindgren[c] has described a recent fault at the base of the Sierra Nevada, near Genoa, where Quaternary deposits have been

[a] Turner, H. W., Post-Tertiary elevation of the Sierra Nevada: Bull. Geol. Soc. America, vol. 13, 1903, pp. 540–541.

[b] Walcott, C. D., The post-Pleistocene elevation of the Inyo Range: Jour. Geol., vol. 5, 1897, pp. 340–348.

[c] Lindgren, W., Age of the auriferous gravels of the Sierra Nevada: Jour. Geol., vol. 4, 1896, p. 902.

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displaced 40 feet, and evidences of still more recent faulting are found in Owens Valley. During the earthquake of 1872, described by Whitney[a] and later by Gilbert, Russell, and others, faulting occurred throughout the valley along the base of the Sierra Nevada.

#### EFFECTS OF OWENS VALLEY EARTHQUAKE.

The more important geologic effects of the earthquake described by Whitney[a] are fissures in the soil or rock, alterations of level of the different parts of the valley, either temporary or permanent, changes in the water courses, and accumulations of water in depressions formed by the earthquake. The author says:

> From Haway Meadows to Big Pine Creek we met frequent cracks in the earth, areas of sunken ground, depressions partly filled with water, and regions where motions of the surface soil had taken place either in a vertical or horizontal direction. The direction of these fissures is almost always nearly parallel with that of the base of the mountains, although in a few instances they run diagonally across the valley. . . . Near Big Pine . . . there is a series of extensive fissures, which may be traced uninterruptedly for several miles. In one place an area of ground 200 or 300 feet wide has sunk to the depth of 20 or 30 feet in places, leaving vertical walls on each side, and these depressions have become partly filled with water, so that ponds have been formed of no inconsiderable size. One noticed was fully one-third of a mile in length, and would have been much larger had not the depression been so situated as to afford partial drainage of the area at one end, so that the basin could not be entirely filled. . . . There are several places in the valley where fissures in the ground have crossed roads, ditches, and lines of fences, and where evidence has been left of an actual moving of the ground horizontally as well as vertically. One of these instances of horizontal motion is seen on the road from Bend City to Independence, about 3 miles east of the latter place. Here, according to a careful diagram of the locality drawn by Captain Scoones, it appears that the road running east and west has been cut off by a fissure 12 feet wide and the westerly portion of it carried 18 feet to the south. The same thing was noticed by us at Lone Pine and Big Pine with regard to fences and ditches, the horizontal distance through which the ground had been moved varying from 3 to 12 feet.

The distribution of volcanic vents and hot springs along the supposed fault line at the base of the Sierra Nevada escarpment is suggestive of movement along that line in comparatively recent time. To judge from Walcott's description of the Waucobi region, Lindgren's description of the Genoa region, and Whitney's description of Owens Valley, it is not unlikely that movements may still be in progress. According to Whitney the earthquake of 1872 was the most severe and disastrous that had been known on the Pacific coast. The shock was felt over the greater part of California and Nevada and southward far into Mexico. The area of greatest disturbance and greatest destruction of life and property was in Owens Valley along a line parallel with the face of the Seirra Nevada.

## UNDERGROUND WATERS.

### ARTESIAN CONDITIONS.

#### GENERAL STATEMENT.

From the descriptions of the geology and structure it is evident that Owens Valley is a well-defined structural basin formed by the older rocks and partly filled with younger sediments. These sediments, which were accumulated both as lake deposits and as débris from near-by mountain slopes, vary greatly in physical character. Lenticular deposits of sand, clay, and gravel occur in the valley fill, and at the sides wedge-shaped masses of coarse mountain wash are probably interbedded with the finer lake deposits. The extent and distribution of the various kinds of material composing the valley fill can only be conjectured, since the well data obtained are insufficient to establish definite relations between them.

The outline of the basin, together with such indications of the structure of the fill as could be obtained, indicates that the valley is a well-defined artesian basin; but whether the underground conditions are such as to produce flowing wells over a considerable portion of the basin can not be stated. A number of wells have been sunk in the valley to moderate depths

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[a] Whitney, J. D., The Owens Valley earthquake: Overland Monthly, June, 1872.

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VIEW FROM "THE MEADOW" ON THE EASTERN SLOPE OF MOUNT WHITNEY.

Showing precipitous cliffs and the glaciated character of the bottom of the gorge.

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and some of them yield flows. No definite records of these wells have been preserved, and all the available well data are insufficient to furnish a thorough knowledge of the underground conditions.

WELL RECORDS.

*Inyo Development Company.*—A well at Keeler owned by the Inyo Development Company is the only one in Owens Valley having a strong artesian flow. It was drilled in 1902, is 465 feet deep, and penetrates 7 gravel layers, all of which contain water under strong pressure. For the upper 190 feet the well is cased with 6-inch pipe, inside of which there is a 4-inch pipe extending from the surface to the bottom. The first flow was found at a depth of 85 feet. The water flowing from the outer casing enters the bottom of the pipe at a depth of 190 feet and is under sufficient pressure to rise 20 feet above the surface. It is too saline for use, as it contains large quantities of "alkali," common salt, calcium carbonate, hydrogen sulphide, etc. The water from the 465-foot level is much better, but it is not used for domestic purposes on account of its large content of hydrogen sulphide. It seems, however, to be comparatively free from "alkali," salt, and lime, as it has been used satisfactorily for two years in the boilers of the soda works. The pressure from the lower horizon lifts the water in a pipe 35 feet above the surface. Nothing was learned regarding the five other water-bearing horizons which were encountered. The well flows about 550 gallons per minute, and since the casings are not perforated this amount enters only at the bottoms of the two pipes. It is evident that a much greater supply could be obtained by using perforated casings, so as to admit water from the other five artesian horizons. Both horizons furnishing water contain natural gas, which escapes with the water at the surface. A preliminary test indicated that the well yields about 1 cubic foot of gas per second. It has satisfactory illuminating properties and might be used to advantage if obtained in sufficiently large quantities.

*Olanche.*—A well near Olanche 80 feet deep failed to obtain artesian water. The material penetrated in this boring was largely granite wash and sand.

*Dodge Brothers' well.*—The Dodge Brothers have made three attempts to obtain artesian water near Lone Pine. The deepest boring went down 160 feet. In each case the attempt failed, probably in large measure on account of the use of unsuitable machinery.

*Spear's well.*—A well at Lone Pine, owned by Mr. R. C. Spear, has a depth of 184 feet No coarse gravel or bowlders were found, and the boring was stopped by hard rock which the drill could not penetrate. No water was struck under pressure sufficient to yield a flow.

*Wrinkle's well.*—About 6 miles north of Lone Pine a well on Wrinkle's ranch, 80 feet deep, yields a slight flow.

*Roeper's well.*—Mr. J. C. Roeper has a 7-inch well 250 feet deep on his farm in sec. 30, T. 14 S., R. 36 E. Several horizons were encountered with water under sufficient pressure to cause a slight flow. Since its construction the well has practically ceased to flow and now yields scarcely enough water for domestic use.

*Well near Black Rock Spring.*—A well about 10 miles north of Independence was bored to a depth of 180 feet. Nothing except detrital material was encountered. Water was found from a depth of 5 feet downward, but it was not under hydrostatic pressure.

*Coe's wells.*—Three wells have been bored by Mr. J. H. Coe. The first, in sec. 3, T. 9 S., R. 34 E., is a 5-inch well, 160 feet deep. Three water-bearing strata were found, separated by layers of blue clay, but no water was obtained under pressure sufficient to produce a flow. The second well, in sec. 4, T. 9 S., R. 34 E., is 175 feet deep. In this well several gravel strata were encountered containing water under some pressure, but yielding no flow. The third well, in sec. 26, T. 9 S., R. 34 E., is 180 feet deep. The material penetrated consists of alternating layers of gravel and clay. Water rose a short distance in this well.

*Bishop.*—There are two small flowing wells at Bishop, but no record of them could be obtained. They are drilled wells and are said to be about 200 feet in depth. The yield is only a few gallons per minute and the pressure is less than 3 pounds. Had the location been on ground a few feet higher the water would not have flowed. On the other hand, a well on lower ground might strike a larger flow.

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*Longley's well.*—Mr. A. W. Longley has a well about 6 miles west of Bishop, in Round Valley. It is 401 feet deep and is nonflowing, but it supplies by pumping all the water desired.

*Minor wells.*—In addition to the wells already described there are several places in the valley where pipes driven 20 to 30 feet yield flowing water. While the water in these wells, as well as in those at Bishop, is under more or less hydrostatic pressure, this pressure is so slight that the wells are of small value.

### FLOWING AREA.

From a consideration of the wells just described it is evident that the only place within Owens Valley where conditions of flow worthy of note are now known to exist is at Keeler.[a] Considered as a whole, however, the valley is an artesian basin in the sense that underground water exists in it under more or less hydrostatic pressure; but the basin is small and the catchment area is practically limited to the space between the confining mountains. No considerable volume of artesian water from a catchment area outside of the valley proper enters Owens Valley. The outcrops of sedimentary formations to the east are of small extent and in a desert region, while the granite to the west precludes all possibility of any notable underflow from that direction. The underground supply therefore is derived mainly from the water entering the valley as streams from the Sierra Nevada, which finds its way downward through the gravels. Hence any artesian conditions which may exist are confined to the narrow limits of the valley floor.

The flowing wells at Bishop and Keeler, situated, as they are, near the opposite extremities of the valley, might suggest that the conditions are favorable for flowing wells throughout the valley, but several wells between these two localities have penetrated at least to the level of the upper horizon at Keeler without obtaining flows. It is worthy of note in this connection that in the Keeler well the lower flow has a greater pressure than the upper, the water from the 190-foot level rising 20 feet and that from the 465-foot level 35 feet above the surface. It is possible that wells deeper than those which have failed might find flowing water throughout the valley.

There are two possible structures of the valley fill to be considered in connection with the subject of artesian conditions. On the one hand it may consist of comparatively uniform and continuous layers of alternating pervious and impervious material with moderately regular successions throughout the valley. In this case a flowing well at one point, as at Keeler, would indicate a reasonable possibility of procuring flowing water at other localities similarly situated. On the other hand, the distribution of the pervious and impervious material may be irregular, in which case isolated bodies of water-bearing sands may occur, yielding flowing wells, while a few miles distant very different conditions may prevail.

### NONFLOWING AREA.

A large amount of water under no hydrostatic pressure occurs throughout Owens Valley. All the shallow wells encounter it within a few feet of the surface, and the bored wells, with the exception of the few just described, show water without hydrostatic pressure to a depth of nearly 200 feet. These wells penetrate layers of sand and gravel separated by layers of clay. The absence of hydrostatic pressure, however, indicates that the porous beds may be so intimately connected that they virtually form one body of sediment through which the water has free communication.

## UTILIZATION OF UNDERGROUND WATERS.

### PUMPING PLANTS.

Pumping water for irrigation has received but little attention thus far in Owens Valley. No pump, so far as could be learned, has ever been given a trial in the valley, and as there

[a] It is possible that the strong flow at Keeler is due in some measure to the pressure of the natural gas. The gas escaping with the water lightens the column in the well and helps to raise the water, a principle utilized in wells using the "air lift."

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are no experiments from which inference may be drawn the subject must be considered entirely from surface indications.

Since the valley fill is composed largely of loose detrital material, it has a large capacity for holding water, and since the valley is an inclosed basin, with the granite extending continuously across it south of Owens Lake, there is little opportunity for water to escape through underground passages. As there is a continuous inflow, amounting to about 395,000 acre-feet per year, and as this inflow passes over loose detrital matter, there is large opportunity for water to pass underground. All things considered, Owens Valley presents ideal conditions for the accumulation of underground water. Some of the observed facts bearing on this subject are as follows:

There are many places throughout the bottom lands where small swamps and lowlands producing swamp vegetation indicate that water is near the surface. The wells throughout the valley contain water within a few feet of the surface. The water table on the Sierra Nevada side is somewhat steeply inclined, owing to the numerous streams entering the valley from those mountains. Cellars were observed with water a foot or more in depth and having a distinct current toward the lowlands, which indicates a somewhat rapid rate of underflow. There are wells into which water flows in streams from the sides near the top and from which it escapes at a lower level. Streams from the mountains diminish in volume to a notable extent as they flow over the detrital matter, the smaller ones passing completely beneath the surface. In the lava fields north of Independence water becomes confined beneath the sheets of lava and issues as large springs. Black Rock spring is a good example and is said to yield about 3,500 gallons per minute. Soldier spring, a few miles farther north, yields about 2,500 gallons per minute.

A comparison of the coarse detritus, large water supply, and closed condition of the basin of Owens Valley with the conditions in other regions where the underground waters have been developed indicates that the pumping of water for irrigation in this valley might be made very successful. At present much land is being injured by the misuse of water. Small swamps are being developed in many places, especially in the vicinity of Bishop, by the diversion of too much water. Lands which were formerly part of the unproductive desert have been changed into unhealthy swamps. A system of pumps might be so arranged as not only to utilize the underground waters, but to drain the land wherever necessary.

### POWER PLANTS.

Many of the streams entering Owens Valley from the higher portions of the Sierra Nevada are of sufficient volume and gradient to produce a large amount of power. These streams are all mountain torrents, and numerous places are available for the establishment of power plants at no great distance from the lowlands of the valley. There is no lack of available power and no obvious reason why it should not be employed in raising the underground waters of the valley for irrigation or used in any other manner desired.

## RESERVOIR SITE.

Preliminary surveys of Long Valley have been made by the Reclamation Service to determine the practicability of converting this depression into a storage reservoir. The dam site for this project is at the lower end of Long Valley, where Owens River cuts a narrow gorge in the recent volcanic rocks. The surplus water of Owens River impounded in this reservoir would be used in reclaiming the desert lands of the lower part of Owens Valley.

Long Valley is a shallow depression about 15 miles long and 8 miles wide nearly surrounded by volcanic rocks. It may be due in some measure to local subsidence, but is more probably due to the deposition of volcanic material as a dam across a portion of an older valley. This created a lake in Long Valley, in which were deposited the Quaternary sediments shown on a geologic map of this region by Spurr.[a] This lake was evi-

[a] Spurr, J. E., Bull. U. S. Geol. Survey No. 208, 1903.

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dently of short duration, for the beach lines are not continuous and are nowhere prominent, and the delta deposits formed by the streams which entered the lake are comparatively small.

There was at first some doubt concerning the ability of the tuff to hold the water of the reservoir, for it is of a soft, spongy nature, easily crushed, though not easily fractured. Subsequent tests have shown, however, that the rock is very resistant and sufficiently impervious for all required purposes.

## EFFECT OF SEISMIC DISTURBANCES.

In the west end of Long Valley the largest hot springs of the region are found. The mud geyser described on page 9 is also in this vicinity. The most recent volcanic craters of the region, of which Panum Crater (Pl. V, *A*) is an example, occur a few miles to the north of the springs, and the zone of faulting believed to be at the foot of the Sierra Nevada passes near if not actually through Long Valley. It is believed by many geologists that a slipping in this fault zone caused the earthquake of 1872, described by Whitney in the article previously quoted (p. 12). There is no reason to suppose that disturbances of this kind are at an end and that an earthquake similar to the one of 1872, which has been recognized as one of the most severe shocks ever experienced in America, should not be repeated at any time [a] A consideration of the surface movements, both temporary and permanent, which caused that shock and of the fact that the proposed reservoir location is near the line of faulting, indicates the possibility that future earthquakes may bring serious consequences to any system of water storage in Owens Valley. On the other hand, more than a quarter of a century has passed without notable disturbance of the region.

## STRUCTURAL MATERIALS.

### BUILDING STONE.

Granite of excellent quality for building purposes is found throughout the Sierra Nevada west of Owens Valley. An exposure of this rock occurs within a few miles of the site of the proposed dam The andesitic tuff is also used to some extent in this region as a building stone. It is so soft that it may be hewn with an ax, but it is surprisingly resistant to strain and to the influence of the weather Exposed cliffs 50 to 150 feet high maintain rugged and sharp outlines. The material often changes within short distances from a soft ash to a well-consolidated tuff.

### MATERIAL FOR CEMENT.

When the investigation of the Owens River project was undertaken by the United States Reclamation Service, it was suggested by J. B. Lippincott, engineer in charge, that the volcanic ash known to exist in the vicinity of the reservoir site might be mixed with Portland cement for use in the construction of the proposed dam and that this might greatly reduce the cost of construction. During the course of the investigation, however, it was discovered that limestone, clay, and a natural cement material also occur in abundance in Owens Valley.

It was found that the volcanic rocks in the vicinity of Long Valley (see p. 8) are, so far as observed, fairly uniform in character. Samples were taken, therefore, at the site of the proposed dam, in order that tests might be made to gain some knowledge of the strength of the abutments and of the cement-making qualities of the tuff. At the dam site the rock is more resistant and more uniformly consolidated than in some other localities, but does not differ in other respects from the less consolidated portions. The tuff has not yet been tested for cement making, but some of its physical properties, as ascertained by the division of physical and chemical research of the United States Geological Survey, are as follows: [b]

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[a] The San Francisco earthquake occurred after the above paragraph was written.
[b] Data furnished by J. C. Clausen, engineer of the United States Reclamation Service.

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*A*. PANUM CRATER, NEAR MONO LAKE.

The rim of the crater is composed of loose volcanic cinders and the central core of somewhat scoriaceous obsidian.

*B*. CROOKED CREEK NEAR LONG VALLEY DAM SITE.

A gorge carved in the volcanic tuffs south of Long Valley.

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*Physical properties of tuff from Long Valley, California.*

| | |
|---|---|
| Specific gravity, dry | 1.53 |
| Specific gravity, saturated with water | 1.91 |
| Gain in weight after saturating with water, per cent | 24 |
| Weight per cubic foot dry, pounds | 95.62 |
| Weight per cubic foot, saturated with water, do | 119.37 |

The Bureau of Ordnance, Department of the Navy, reports on the crushing strength of this rock as follows: Test No. 1 crushed at 2,056 pounds per square inch; test No. 2 crushed at 1,725 pounds per square inch. Edward Duryee, of the United States Reclamation Service, reports the specific gravity of the same kind of rock as 2.19.

Limestones and marble are abundant in Owens Valley, especially on the flanks of the White Mountains. Clay is found in the valley floor and in the form of shale and slate on the mountain slopes. It is thought that these materials may be found suitable for the manufacture of cement.

In the western bluff of Owens Lake, near the mouth of Cottonwood Creek, occurs a stratum of fine material about 8 feet thick, which seems to be composed of a mixture of fine volcanic ash and clay. J. F. Holloway, who owns a ranch near this point, has taken some interest in this deposit in the hope that it may prove of value in the construction of canals. At his request the material was examined by Mr. Cooper, formerly State mineralogist of California, who states that "with the addition of lime the material would make a good Portland cement." The material was also examined for fineness by E. C. Preble of Chicago. Of two samples tested by him, 11.9 per cent and 22 per cent, respectively, were left on a 100-mesh sieve. He suggests that with the addition of proper quantities of lime a good cement could be manufactured. A deposit of this material is shown in Pl. V, *A*. Where the blocks fallen from the cliff have been acted on by the lake water, the material has been distinctly hardened, owing to the deposition of carbonate of lime, and is notably changed in chemical composition. Samples of both the original and the altered material were collected, and have been analyzed by Edward Duryee, of the United States Reclamation Service, as follows:

*Analysis of cement rock from Owens Lake.*

| | Unaltered material. | Altered material. |
|---|---|---|
| Silica | 71.50 | 14 |
| Oxide of iron and alumina | 22.02 | 5.64 |
| Carbonate of lime | 2 | 74.98 |
| Carbonate of magnesia | 2.40 | 4.37 |

Commenting on these analyses, Mr. Duryee says: "The analysis of No. 2 [the altered material] indicates that the material is suitable for making Portland cement by burning it at the proper temperature. If further examination shows the deposit to be extensive and uniform in composition and free from insoluble sand, it is a Portland cement rock."

## CLIMATE.

### RAINFALL.

Owens Valley is cut off from the supply of moisture on the east and south by a long stretch of desert and on the west by high mountains. As previously stated the moisture-laden winds from the Pacific Ocean lose much of their moisture in passing over the Sierra Nevada before reaching the Owens Valley region. The result of these conditions is the heavy precipitation near the top of the range, while desert conditions prevail in the valley only a few miles to the east. The available information regarding the rainfall in the valley is contained in the following tables:



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*Record of precipitation at Bishop Creek, Inyo County, Cal.*[a]

[Lat., 37° 21′; long., 118° 22′; elevation, 4,450 feet. Authority, Southern Pacific Railroad.]

| Year. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1883-84 | 0.12 | 0.11 | 0 | 0.38 | 0.62 | 0.64 | 0.94 | 0.05 | 0 | 0 | 0 | 0 | 2.86 |
| 1884-85 | 0 | 0 | 0 | 1 | 0 | 0 | .67 | .14 | 0 | 0 | 0 | 0 | 1.81 |
| 1885-86 | 0 | .02 | 0.35 | 0 | 1.03 | 0 | .50 | .38 | 0 | 0 | 0 | 0 | 2.28 |
| 1886-87 | 0 | 0 | 0 | .20 | .65 | 1.58 | 0 | .35 | 0.55 | 0.35 | 0 | 0 | 3.68 |
| 1887-88 | .15 | .15 | .05 | 1.10 | 1.37 | .47 | .05 | 0 | 0 | .35 | 0.20 | 0 | 3.89 |
| 1888-89 | 0 | 0 | 1.72 | .40 | .10 | .50 | 1.46 | .12 | .30 | 0 | 0 | 0 | 4.60 |
| 1889-90 | 0 | .03 | .35 | 1.20 | 4.75 | .30 | 0 | 0 | 0 | 0 | 0 | 0.50 | 7.13 |
| 1890-91 | .69 | 0 | 0 | 1 | 0 | 3.70 | .28 | 0 | 2.90 | 0 | 0 | .03 | 8.60 |
| 1891-92 | .19 | 0 | 0 | 3.52 | .10 | .70 | 1.10 | 0 | .25 | T. | 0 | 0 | 5.86 |
| 1892-93 | 0 | .20 | 1.42 | 2.27 | 1.22 | 1.12 | .15 | 0 | 0 | 0 | 1.05 | T. | 7.43 |
| 1893-94 | .19 | 0 | .10 | .49 | .30 | .75 | .09 | .05 | T. | .35 | T. | .23 | 2.55 |
| 1894-95 | T. | 0 | 0 | 1.18 | 1.10 | .50 | .22 | .29 | .15 | .11 | .21 | .07 | 3.83 |
| 1895-96 | T. | .16 | .15 | T. | 1.07 | 0 | .60 | .05 | .03 | 0 | .57 | .06 | 2.69 |
| 1896-97 | .05 | T. | T. | .16 | .32 | 1.67 | 1.75 | 0 | .12 | T. | .01 | .05 | 4.13 |
| 1897-98 | .09 | .39 | T. | .49 | .05 | .13 | T. | .21 | .27 | T. | T. | .06 | 1.69 |
| 1898-99 | .41 | 0 | .21 | .11 | 1.65 | 0 | T. | .64 | .02 | 0 | 0 | .05 | 3.09 |
| 1899-1900 | 0 | .14 | .05 | 1.05 | .49 | .01 | .54 | .60 | .34 | .12 | T. | 0 | 3.34 |
| 1900-1901 | .39 | .03 | 2.69 | .17 | 4.89 | 1.01 | T. | .50 | 1.29 | T. | 0 | .93 | 11.90 |
| 1901-2 | 0 | .81 | .61 | .12 | .07 | .55 | 1.53 | .61 | .06 | 0 | T. | .12 | 4.48 |
| 19-year mean. | | | | | | | | | | | | | 4.52 |

[a] Water-Sup. and Irr. Paper No. 81, U. S. Geol. Survey, 1903, p. 426.

*Record of precipitation at Keeler, Inyo County, Cal.*[a]

[Lat., 36° 35′; long., 117° 50′; elevation, 3,622 feet. Authority, Southern Pacific Railroad.]

| Year. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May. | June | July. | Aug. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1883-84 | | | | | | | | 0.20 | 1.60 | 0.80 | 0 | 0.20 | [b]2.80 |
| 1884-85 | 0 | 0 | 0 | 0.70 | 0 | 0 | 0.12 | .82 | 0 | .08 | 0 | .11 | 1.83 |
| 1885-86 | 0 | 0.25 | 0.65 | .36 | 0.49 | 0.14 | .60 | .40 | 0 | 0 | .14 | .08 | 3.11 |
| 1886-87 | 0 | .01 | .08 | 0 | T. | .93 | 0 | 1.14 | .04 | T. | .52 | 0 | 2.72 |
| 1887-88 | 1.08 | .84 | .01 | .48 | .70 | 1.21 | .30 | .12 | .30 | .20 | .17 | .10 | 5.51 |
| 1888-89 | .06 | 0 | 1.68 | .82 | .04 | T. | .52 | .12 | .06 | .01 | 0 | T. | 3.31 |
| 1889-90 | .08 | .56 | .05 | .56 | .42 | .01 | T. | .10 | .20 | 0 | T. | 1.71 | 3.69 |
| 1890-91 | .93 | .03 | .12 | .22 | 0 | 1 | 2.01 | 0 | .37 | .30 | .06 | .02 | 5.06 |
| 1891-92 | .19 | .04 | 0 | .31 | .26 | .19 | .32 | 0 | .56 | T. | 0 | 0 | 1.87 |
| 1892-93 | T. | .81 | .11 | .54 | .71 | .75 | 1.50 | 0 | T. | 0 | 1.41 | T. | 5.83 |
| 1893-94 | T. | T. | .03 | 1.48 | T. | .29 | .01 | T. | T. | T. | .11 | 0 | 1.92 |
| 1894-95 | 0 | 0 | 0 | 1.05 | .35 | 1.15 | T. | .25 | T. | T. | T. | T. | 2.80 |
| 1895-96 | T. | 0 | 0 | T. | .45 | 0 | T. | T. | .15 | T. | .25 | 1.42 | 2.27 |
| 1896-97 | .50 | T. | 0 | .25 | .10 | .27 | .13 | 0 | T. | 0 | 0 | .19 | 1.44 |
| 1897-98 | .14 | .15 | T. | T. | 0 | 0 | 0 | .05 | 0 | 0 | 0 | 0 | .34 |
| 1898-99 | T. | 0 | T. | .30 | .40 | .45 | 0 | .01 | T. | .50 | T. | T. | 1.66 |
| 1899-1900 | 0 | T. | 1.75 | T. | T. | 0 | .16 | 1.25 | .23 | T. | .10 | T. | 3.49 |
| 1900-1901 | .35 | .09 | .45 | 0 | .75 | .25 | 0 | T. | .40 | 0 | 0 | .90 | 3.19 |
| 1901-2 | 0 | .50 | 0 | 0 | T. | .25 | 1.25 | 0 | 0 | 0 | T. | T. | 2 |
| 18-year mean. | | | | | | | | | | | | | 2.89 |

[a] Water-Sup. and Irr. Paper No. 81, U. S. Geol. Survey, 1903, p. 427.
[b] Year incomplete.

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*Record of precipitation at Camp Independence, Inyo County, Cal.*[a]

[Lat., 36° 50′; long., 118° 10′; elevation, 4,598 feet. Authority, United States War Department.]

| Year. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1865-66 | ..... | ..... | 0 | 0.65 | 2.42 | 0 | 0 | 0.16 | ..... | ..... | ..... | ..... | [b]3.23 |
| 1866-67 | 0 | 0.32 | 0 | 2.27 | 0 | 1.63 | 4.76 | .53 | 0.76 | 0 | 0.01 | 1.15 | 11.43 |
| 1867-68 | 0.07 | .32 | 0.21 | 12.19 | 5.46 | 0 | 0 | .40 | .71 | 0 | .10 | 0 | 19.46 |
| 1868-69 | 0 | .74 | .44 | 1.17 | .16 | 0 | .32 | .11 | .36 | 0 | .03 | 0 | 3.33 |
| 1869-70 | 0 | 0 | .14 | 0 | .20 | 1.36 | 0 | .21 | .27 | 0 | .35 | .10 | 2.63 |
| 1870-71 | 0 | 1.10 | 0 | 1 | 0 | 1.28 | 0 | 0 | 0 | .30 | 0 | 0 | 3.68 |
| 1871-72 | 0 | 0 | .65 | 4.70 | 0 | .30 | .28 | .55 | .18 | 0 | .28 | .12 | 7.06 |
| 1872-73 | 0 | 0 | 0 | 1.18 | 0 | .40 | 0 | 0 | 0 | 0 | 0 | .05 | 1.63 |
| 1873-74 | .10 | 0 | 0 | 3.40 | 2.40 | 1 | 0 | 0 | 0 | .01 | .15 | 0 | 7.06 |
| 1874-75 | .40 | .80 | .40 | 0 | 1.73 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.33 |
| 1875-76 | .01 | 0 | .66 | .62 | 1.51 | .70 | .87 | 0 | 0 | .15 | .19 | .56 | 5.27 |
| 1876-77 | .16 | .26 | 0 | 0 | .76 | 0 | 0 | .59 | .69 | 0 | 0 | 0 | 2.46 |
| 1891-92 | ..... | ..... | ..... | ..... | ..... | ..... | .62 | ..... | .96 | .07 | T. | T. | [b]1.65 |
| 1892-93 | 0 | .35 | .23 | 1.61 | 1.51 | 2.91 | .98 | .02 | T. | 0 | .77 | T. | 8.38 |
| 1893-94 | T. | 0 | .10 | .75 | .12 | .42 | .09 | .02 | .10 | .11 | .12 | .51 | 2.34 |
| 1894-95 | T. | 0 | 0 | 1.89 | 1.24 | 1.18 | .12 | T. | .01 | T. | T. | .04 | 4.48 |
| 1895-96 | T. | .83 | .67 | .08 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | [b]1.58 |
| 1897-98 | ..... | ..... | ..... | ..... | ..... | ..... | 0 | .16 | .23 | T. | T. | .11 | [b],50 |
| 1898-99 | .20 | 0 | .10 | .20 | .54 | T. | .01 | .02 | .03 | .37 | .01 | .06 | 1.54 |
| 1899-1900 | T. | .30 | .85 | .56 | .31 | .05 | .67 | .62 | .22 | .04 | .08 | T. | 3.70 |
| 1900-1901 | .75 | .01 | 1.34 | .13 | 2.81 | .64 | .05 | T. | .36 | 0 | .10 | .32 | 6.51 |
| 1901-2 | 0 | .65 | .22 | .06 | .04 | 1.69 | 1.05 | .17 | .04 | .01 | .17 | .13 | 4.23 |
| 18-year mean | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 5.47 |

[a] Water-Sup. and Irr. Paper No. 81, U. S. Geol. Survey, 1903, p. 427.
[b] Year incomplete.

These tables show that the precipitation is not only slight but exceedingly variable, the yearly totals ranging from a maximum of 19.46 inches to a minimum of 0.34 inch, while the average is 4.14 inches.

No records are available for the Sierra Nevada region, but the annual precipitation is about 50 inches.[a] The amount of rainfall in the mountainous district is much greater than in the valley. This fact is indicated by the condition of the vegetation in the two districts. The mountains are covered with a luxuriant forest, characteristic of a well-watered region, while in the valley outside of the immediate influence of the streams there is only a scant and stunted growth of plants characteristic of the desert region of the Great Basin.

## EVAPORATION.

*Rate at Owens Lake.*—The waters entering Owens Lake have no means of escape except by evaporation, but these waters have been disappearing for several years and the lake itself has greatly decreased in volume. During the last ten years the surface of the lake has lowered 16 feet and in 1904 it lowered 2.5 feet. According to measurements furnished by J. C. Clausen, of the United States Reclamation Service, the volume of water entering the valley during one year, August, 1903, to July, 1904, was about 395,000 acre-feet, of which 297,000 were diverted for irrigation and 64,000 entered Owens Lake, leaving 34,000 which presumably joined the underflow.[b] Furthermore, a large though unknown propor-

[a] See map, Water-Sup. and Irr. Paper No. 81, U. S. Geol. Survey, 1903, p. 12.
[b] The total includes the waters of 18 of the tributary streams, of which occasional measurements were made and the discharge estimated. The error is not great, as the discharge of these streams is small compared with that of Owens River. The measurements so far as they are available are to be found in the reports of progress of stream measurements, Water-Sup. and Irr. Papers Nos. 100, 134, and 177, U. S. Geol. Survey.

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tion of the water diverted for irrigation must have found its way beneath the surface. This water moves slowly toward the lowest part of the basin, where it is eventually lost by evaporation either from the land surface to which it is brought by capillary action or from the lake.

Based on the loss from the lake in 1904, the annual rate of evaporation is 30 inches more than the total inflow. The 64,000 acre-feet of water entering the lake and lost from its 75 square miles of evaporating surface add about 16 inches to the annual rate of evaporation. Several small streams whose waters were not measured enter the lake and the volume entering as underflow, although unknown, must be large. A rate of evaporation sufficient to dispose of these unmeasured waters must be added, which makes an annual evaporation of considerably more than 46 inches from the surface of the lake.

*Rate at Bishop.*—During 1904 evaporation measurements were carried on at Bishop, Cal., by the engineers of the United States Reclamation Service, with the following result:

*Evaporation at Bishop, Cal.*

[Data furnished by R. J. Taylor.]

| | Inches. | | Inches. |
|---|---|---|---|
| January 5-31, 1904 | 4.09 | September | 3.83 |
| February | 2.21 | October | 2.82 |
| March | 4.48 | November | 1.73 |
| April | 6.41 | December | 3.21 |
| May | 11.02 | January 1-4, 1905[a] | .26 |
| June | 7.88 | | 60.13 |
| July | 6.95 | | |
| August | 5.24 | | |

## TEMPERATURE.

The temperature of Owens Valley is subject to great and sudden changes, owing to the wide differences of altitude within the region. The average temperature is moderate, as is shown by the accompanying table of mean temperatures. It is not uncommon for killing frosts to occur late in the spring, nor is it unusual, on the other hand, for the temperature to reach 100° or more during the summer months.

*Monthly mean temperature at Independence, Cal.*

[Data by J. J. McLean, observer, U. S. Weather Bureau.]

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1894 | | | | | | | | | | | | 38.4 | |
| 1895 | 37.8 | 45.5 | 49.2 | 57.3 | 65.6 | 71.6 | 78 | 76 | 68.3 | 60 | 48.3 | 37.8 | 58 |
| 1896 | 43.2 | 47.2 | 44 | | | | | | | | | | |
| 1897[a] | | | | | | | | | | | | | |
| 1898 | | | | 62 | 62.1 | 74.2 | 80.4 | 80.1 | 72 | 60 | 48.2 | 39.7 | |
| 1899 | 40.2 | 46.5 | 50.5 | 59.4 | 60 | 74.2 | 80.4 | 72.6 | 74.6 | 55.4 | 49.4 | 43.1 | 58.8 |
| 1900 | 46.6 | 48.1 | 54.9 | 52 | 65.8 | 75.4 | 79.4 | 72.4 | 63.5 | 58.8 | 50.4 | 43.4 | 59.2 |
| Mean | 42 | 46.8 | 49.6 | 57.7 | 63.4 | 73.8 | 79.6 | 75.3 | 69.6 | 58.6 | 49.1 | 40.5 | 58.7 |

[a] Station closed.

## UNDRAINED LAKES AS REGISTERS OF CLIMATE.

### OWENS LAKE.

*Physical character.*—Owens Lake was originally described[b] as having an area of about 110 square miles, with an average depth of 9 feet 10 inches and a density of 1.051. The only

[a] The total for January, 1905, is 2.05; in order to make the table cover a complete year four thirty-firsts of that amount is included with the 1904 measurements.

[b] Loew, Oscar, Ann. Rept. U. S. Geog. Surv. W. 100th Mer., 1876, p. 189. Goodyear, W. A., Eighth Ann. Rept. State Mineralogist California, 1888, p. 227.

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known forms of animal life inhabiting the water were infusoria, alkali shrimps (*Artemia salina*), and the larvæ of the alkali flies (*Ephydra*), which developed in great numbers. Some of the conditions described by former writers have materially changed in recent years. At Keeler, on the eastern shore of Owens Lake, the Inyo Development Company has an extensive plant for the extraction of soda from the waters of the lake. This plant has been in operation for about twenty years and the lake has been observed from a commercial standpoint during that time. Mr. N. Wrinkle, the superintendent of the soda works, has kindly furnished the following information.[a]

The density of the water has increased to a point where bicarbonate of soda precipitates during the winter months without concentration by evaporation. During the past three years—1902 to 1904—the surface of the lake has lowered at the rate of 2.5 feet per year, and it has lowered 16 feet since 1894. Throughout the ten years previous to this date the lake surface remained practically stationary. Formerly alkali flies developed in myriads, as described by various writers, but during the present season (1904), although the larvæ are as numerous as usual, the flies have failed to appear.

It has been assumed that the failure of the larvæ to develop is due to the increasing density of the water. This suggestion is strengthened by the fact that at Mono Lake these flies appeared in as great numbers as usual, and were seen by the writer literally blackening the sands at the water's edge. The water of Mono Lake is much less saline than that of Owens Lake, although it is otherwise similar, as a comparison of the analyses will show.

It is evident from Goodyear's description[b] that the decrease in volume of Owens Lake had a comparatively recent beginning. He writes concerning his visit in 1870: "It is certain that the water at the time of our visit was higher by at least several feet than it had been for some time previously, for at one or two points along the margin of the lake I saw in the shallow water near the shore the dead sagebrush still standing where it grew, but entirely covered by water."

*Chemical character.*—The water of Owens Lake is strongly charged with common salt, sodium carbonate, borax, and minor quantities of other salts. Several analyses of the water have been made.[c]

The earliest analysis, so far as known, was by Professor Phillips, of England, the exact date, however, being unknown. It is as follows:[d]

*Analysis of the water of Owens Lake, California.*

| | Parts per million. | | Parts per million. |
|---|---|---|---|
| Sodium (Na) | 43,395 | Silicate radicle ($SiO_3$) | 908 |
| Potassium (K) | 3,378 | Organic matter | 242 |
| Chlorine (Cl) | 25,478 | | |
| Sulphate radicle ($SO_4$) | 12,929 | | 103,605 |
| Carbonate radicle ($CO_3$) | 17,275 | | |

The following analysis was made by Oscar Loew for the Wheeler Survey.[e]

*Analysis of the water of Owens Lake, California (1876).*

[Specific gravity 1.051.]

| | Parts per million. | | Parts per million. |
|---|---|---|---|
| Sodium (Na) | 21,550 | Magnesium (Mg) | Trace. |
| Potassium (K) | 2,753 | Aluminum (Al) | Trace. |
| Chlorine (Cl) | 13,496 | Borate radicle ($B_4O_7$) | Trace. |
| Sulphate radicle ($SO_4$) | 9,363 | Phosphate radicle ($PO_4$) | Trace. |
| Carbonate radicle ($CO_3$) | 13,240 | Nitrate radicle ($NO_3$) | Trace. |
| Silica ($SiO_2$) | 163 | Organic matter | Trace. |
| Lithium (Li) | Trace. | | |
| Calcium (Ca) | Trace. | | 60,565 |

[a] Personal communication.
[b] Goodyear, W. A., Eighth Ann. Rept. State Mineralogist California, 1888, p. 241.
[c] The values are given in various units in the original reports, but have been reduced to parts per million and to round numbers in order that comparison may be made more readily. Correction is also made for specific gravity.
[d] Bailey, Gilbert E., Saline deposits of California: Bull. California State Mining Bureau No. 24, 1902, p. 95.
[e] Ann. Rept. U. S. Geog. Survey W. 100th Mer., 1876, p. 190. See also Eighth Ann. Rept. U. S. Geol. Survey, pt. 1, 1889, p. 295.

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Ten years later another analysis was made by T. M. Chatard, of the United States Geological Survey. The sample was taken September 17, 1886.[a]

*Analysis of the water of Owens Lake, California (1886).*

[Specific gravity, 1.062 at 25°.]

| | Per cent. | Parts per million. | | Per cent. | Parts per million. |
|---|---|---|---|---|---|
| Silica ($SiO_2$) | 0.28 | 208 | Sulphate radicle ($SO_4$) | 9.73 | 7,080 |
| Potassium (K) | 2.13 | 1,551 | Borate radicle ($B_4O_7$) | .49 | 346 |
| Sodium (Na) | 36.96 | 26,887 | Carbonate radicle ($CO_3$) | 25.16 | 18,300 |
| Calcium (Ca) | .02 | 13 | Chlorine (Cl) | 25.09 | 18,250 |
| Magnesium (Mg) | | 5 | Hydrogen (H) | .10 | 60 |
| Iron (Fe) | .02 | 9 | | | |
| Aluminum (Al) | .03 | 12 | | 100.01 | 72,721 |

Recently a partial analysis of the water of Owens Lake was made by N. Wrinkle, manager of the Inyo Development Company's soda works at Keeler. The sample was taken in July, 1904. Mr. Wrinkle found the specific gravity to be 1.186 and the percentage of contained salts correspondingly great.

In August, 1905, at the writer's request a complete analysis was made by C. H. Stone, of the United States Reclamation Service, as follows:

*Analysis of water from Owens Lake, California (1905).*

[Sample taken August 21.[b] Specific gravity, 1.195.]

| | Parts per million by weight. | | Parts per million by weight. |
|---|---|---|---|
| Silica ($SiO_2$) | 298 | Phosphate radicle ($PO_4$) | 238 |
| Iron and aluminum (FeAl calculated as Al) | 48 | Borate radicle ($B_4O_7$) | 296 |
| Calcium (Ca) | 34 | H (in $HCO_3$, $Na_2HPO_4$, and $CaH_4(PO_4)_2$) | 130 |
| Magnesium (Mg) | 15 | $As_2O_3$ | 111 |
| Potassium (K) | 3,448 | $NO_3$ | 968 |
| Sodium (Na) | 81,176 | Rb | Trace. |
| Lithium (Li) | 57 | Cs | Trace. |
| Sulphate radicle ($SO_4$) | 21,174 | Total solids (by addition) | 213,197 |
| Chlorine (Cl) | 52,898 | Total solids determined | 213,661 |
| Carbonate radicle ($CO_3$) | 52,326 | | |

For convenience of comparison the total solids and densities given in the foregoing analyses are tabulated below. The first analysis, that of Phillips, does not accord with the later ones. The increase in density shown by the others is largely, if not wholly, due to the decrease in the volume of the lake caused by rapid evaporation.

*Increase in salinity of Owens Lake, California.*

| Date of analysis. | Authority. | Total solids (parts per million). | Specific gravity. | Remarks. |
|---|---|---|---|---|
| (?) | Phillips | 103,605 | | |
| 1876 | Loew | 60,565 | 1.051 | |
| 1886 | Chatard | 72,721 | 1.062 | Volume constant since 1876. |
| 1904 | Wrinkle | | 1.186 | Volume decreasing since 1894. |
| 1905 | Stone | 213,660 | 1.195 | Volume of lake constant for 1 year previous to sampling. |

[a] Bull. U. S. Geol. Survey No. 60, 1890, p. 58.
[b] For about one year previous to this date the surface of the lake had remained stationary.

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### MONO LAKE.

*Physical character.*—Mono Lake and its environs have been described by Russell,[a] who shows that the lake had been increasing in volume for twenty-five years previous to the time of his examination, the surface having risen from 15 to 20 feet during that time. To aid in future determinations of changes of level a permanent bench mark was placed at the water's edge on one of the islands in the lake, the water level at that time (November 5, 1883) being 6,380 feet above sea level, as determined by vertical angles from Mount Conness.

During the writer's visit to the lake in the summer of 1904 abundant evidence was found of a recent rise of the water surface. Dead trees and shrubs of varieties that grow only on dry land were seen standing in several feet of water, and a road at the west end of the lake, said to have been used only a few years ago, was covered with water about 4 feet deep. The island on which the bench mark described by Russell was established was not visited by the writer, but at his request William Farrington, a young man living near the lake, later visited this island and found that the bench mark had been submerged, and no measurement was taken.

According to determinations of altitude by the United States Geological Survey[b] the surface of Mono Lake had an altitude of 6,412 feet on July 27, 1898. In making these determinations it was found that the altitude as previously determined was 13 feet too high. According to the later determinations, therefore, the lake surface was 19 feet higher in 1898 than it was in 1883.

*Chemical character.*—The water of Mono Lake is similar in composition to that of Owens Lake, as is indicated by the following analysis:

*Analysis of the water of Mono Lake (1882).*[c]

[Specific gravity, 1.0456 at 15.5°.]

| | Per cent of total solids. | Parts per million. | | Per cent of total solids. | Parts per million. |
|---|---|---|---|---|---|
| Silica ($SiO_2$) | 0.130 | 67 | Sulphate radicle ($SO_4$) | 12.480 | 6,319 |
| Calcium (Ca) | .037 | 20 | Chlorine (Cl) | 22.630 | 11,638 |
| Magnesium (Mg) | .103 | 53 | Borate radicle ($B_4O_7$) | .300 | 154 |
| Potassium (K) | 1.795 | 924 | Carbonate radicle ($CO_3$) | 23.350 | 13,163 |
| Sodium (Na) | 36.810 | 19,312 | Bicarbonate radicle ($HCO_3$) | .360 | 4 |
| Alumina ($Al_2O_3$), Ferric oxide ($Fe_2O_3$) | .005 | 3 | | 98 | 51,657 |

### DISCUSSION.

The statement is sometimes made that a decrease in volume of an undrained lake indicates a change of climate toward aridity and vice versa. In discussing the fluctuations of level of the basin lakes, Mono and Owens lakes among others, King[d] states that the influence of irrigation is too slight to be considered. This opinion seems to have been too generally accepted, and in the case of Owens Lake it will certainly not hold good. According to the measurements previously given (p. 19), 297,000 acre-feet of water were spread over about 40,000 acres of land during one year (1903–4), or enough to make an average depth of nearly 7.5 feet. Since the annual evaporation from a free water surface is about 60 inches, it follows that about one-third of the water sinks into the ground. The rate of evaporation from irrigated land is not known. Were this rate the same as

[a] Russell, I. C., Quaternary history of Mono Valley, California: Eighth Ann. Rept. U. S. Geol. Survey, pt. 1, 1889, pp. 269–394.
[b] Gannett, Henry, Dictionary of altitudes: Bull. U. S. Geol. Survey No. 274, 1906, p. 110.
[c] Chatard, T. M., Bull. U. S. Geol. Survey No. 60, 1890, p. 53; Am. Jour. Sci., 3d ser., vol. 36, p. 149. Russell, I. C., Eighth Ann. Rept. U. S. Geol. Survey, pt. 1, 1889, p. 293.
[d] King, Clarence, Rept. U. S. Geol. Explor. 40th Par., vol. 1, 1878, p. 525.

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from a water surface, about 200,000 acre-feet of water would have been lost by evaporation from the irrigated land. Of the total quantity of water entering the valley during the year 1904 (395,000 acre-feet), 75 per cent was diverted for irrigation and 16 per cent entered Owens Lake as surface flow, leaving 9 per cent unaccounted for. If the rate of evaporation from irrigated land were the same as that from a water surface, 200,000 acre-feet, or 50 per cent of the total inflow, would have been lost from the land, leaving 50 per cent to be divided between surface flow and underflow, of which 16 per cent is known to have been surface flow.

The misuse of water in Owens Valley makes the loss by evaporation much greater than it would be from properly irrigated land. Not all the water diverted for irrigation purposes is used, but a portion is allowed to spread over uncultivated land. For this reason evaporation from the irrigated district is greater than it would otherwise be. The area of irrigated land, about 40,000 acres, is comparable in size to that of the lake, about 48,000 acres. It is evident from the facts stated that the rate of evaporation from the land is high and may be little, if any, less than that from a water surface, and that the volume lost from the land is comparable to that lost from the lake.

During 1903–4, when careful measurements were made of all the water entering Owens Valley, as described on page 19, there was a loss by evaporation of not only all this water (395,000 acre-feet), but an additional amount from the lake represented by a depth of 2.5 feet over 75 square miles, or 48,000 acres—that is, 120,000-acre-feet. Since the valley is an undrained basin and water can escape only by evaporation, it is evident that this loss during the year was 515,000 acre-feet. Had the natural flow of the streams entered the lake the rate of evaporation (disregarding evaporation along the stream courses) in order to lower the surface of the lake 2.5 feet would have been about 128 inches, for in that case the loss would have been from the lake surface alone. Since the actual rate of evaporation has been found to be only 60.13 inches at Bishop, the rate of 128 inches from the surface of Owens Lake is improbable.

Again, if only the measured volume of water, 395,000 acre-feet, which would naturally have entered the lake be considered, a rate of evaporation of about 98 inches from the lake surface would be required in order that the surface might remain stationary. Even this rate is greater than can reasonably be assumed, and it follows that the undisturbed flow of the streams entering Owens Valley would probably increase the present volume of the lake and restore it to its original size, if it would not actually increase that size.

## CONCLUSION.

Since Mono and Owens lakes are comparable in size, location, and chemical composition, and derive their water supply from the same mountain range, it is natural to suppose that a change of climate would affect both alike, yet Mono Lake is increasing in volume, while Owens Lake is decreasing. The drainage into Mono Lake has never been disturbed to any appreciable extent by artificial means, such as irrigation. If a rise or fall of the water level of an undrained lake is an adequate indication of climatic change, Mono Lake might show such a change, for natural conditions are there practically undisturbed. In this case, however, the rise of the water level apparently indicates that the climate has become more humid during the last few years.

The glacier at the summit of Mount Lyell (Pl. VI, *A*) gives confirmatory evidence that an increase rather than a decrease in humidity has occurred in recent years in this vicinity. This glacier is the largest of the numerous bodies of snow and ice near the headwaters of Owens River and Rush Creek. It drains westward away from Owens Valley, but is at the summit of the main drainage area of the Owens Valley region. Its form and size have been definitely known for about twenty-two years.[a] The writer[b] has previously shown that

[a] See Russell, I. C., Existing glaciers of the United States: Fifth Ann. Rept. U. S. Geol. Survey, 1885, p. 315; Quaternary history of Mono Valley, California: Eighth Ann. Rept. U. S. Geol. Survey, pt. 1, 1889, Pls. XXVII, XXVIII.

[b] Lee, W. T., Note on the glacier of Mount Lyell, California: Jour. Geol., vol. 13, 1905, pp. 358–362.

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*A*. WESTERN LOBE OF LYELL GLACIER.

This glacier is the largest of the numerous bodies of snow and ice near the headwaters of Owens River.

*B*. CREST OF THE HIGH SIERRA AT MAMMOTH MOUNTAIN.

Showing the precipitous eastern face at the left and parts of the gentler western slope at the right. Photograph by J. B. Lippincott.

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during this time no permanent diminution in the volume of the ice has occurred and that the large amounts of snow on the glacier, shown in Pl. VI, *A*, indicate a possible increase in humidity.

From the preceding discussion it is evident that the evaporation from irrigated lands in Owens Valley is very large and that the decrease in volume of water of Owens Lake is due mainly to this cause. The measurements given indicate that if the waters of Owens Valley were allowed to flow naturally into Owens Lake that lake would probably be increasing instead of diminishing in volume, just as Mono Lake is increasing. To judge from present knowledge of the two lakes and of Mount Lyell Glacier, it is evident that the popular belief in a diminution of rainfall in the vicinity of Owens Valley for the last ten years is not supported by the facts, and that if any change of climate is in progress it is toward a more humid rather than a more arid climate.

## RÉSUMÉ.

Owens Valley is a long, narrow, -shaped trough formed mainly by the deformation of pre-Tertiary rocks and partly filled with unconsolidated Tertiary and Quaternary sediments originating as lake deposits, river deposits, and mountain wash. The deformation is assumed to have occurred in the form of crust-block tilting, Owens Valley representing the V-shaped depression between the Sierra Nevada and White Mountain blocks. This assumption is based on the following facts: A succession of lava flows and volcanic craters of recent origin occur along the eastern base of the Sierra Nevada throughout the length of Owens Valley. Hot springs occur in the same zone from the midst of Owens Valley to Mono Lake, and a mud geyser is found at Casa Diablo. Faulting and associated phenomena have been observed in many places along the eastern margin of the Sierra Nevada and also east of the White Mountains. Confirmatory evidence is found in such topographic forms as the inclined peneplain of the western slope of the Sierra Nevada, the cliff-like eastern face, the steep escarpment east of the White Mountains, and the less steep western face.

Owens Valley is a barren desert except where it is reclaimed by the use of water entering as mountain streams. Abundant rainfall occurs in the Sierra Nevada, yielding for this valley an annual water supply of about 400,000 acre-feet. As the streams enter the valley they pass over unconsolidated detritus, into which much of the water sinks.

Flowing wells occur in Owens Valley, but the limits of the district in which such wells are obtainable are undetermined.

A large amount of underground water exists without hydrostatic pressure sufficient to produce flowing wells, but power for pumping this water can be produced from the mountain streams and transmitted to the valley at moderate cost.

Owens Lake has been decreasing in volume for several years, with a corresponding increase in the density of its water. The salinity has reached a point at which the more insoluble salts precipitate. The change is probably due to the loss by evaporation of water diverted for irrigation and not to an increase in the aridity of the climate, as originally supposed.

Faulting and crustal movements of considerable magnitude, accompanied by earthquake shocks, have taken place in Owens Valley within historic time, and there is no evidence that disturbances of this kind are at an end

The proposed Owens Valley reservoir, being located in the fault zone at the base of the Sierra Nevada, would be especially liable to injury from crustal movements.

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# INDEX.


| | Page. |
|---|---|
| Aberdeen, lavas near | 8 |
| Artemia salina, occurrence of | 21 |
| Artesian water. *See* Waters, underground. | |
| Big Pine, bowlders near, view of | 10 |
| Big Pine district, volcanic features of | 8 |
| Bishop, altitude at | 5 |
| evaporation at | 20, 24 |
| wells at | 13, 14 |
| Bishop Creek, rainfall at | 18 |
| Black Rock Spring, well near | 13 |
| Building stone, character and distribution of | 16 |
| Camp Independence, rainfall at | 19 |
| Carirlfex newberryi, occurrence of | 7 |
| Casa Diablo, mud geysers at | 7 |
| Cement materials, character and distribution of | 16–17 |
| Cement rock, analyses of | 17 |
| Chatard, T. M., analysis by | 22 |
| Clausen, J. C., water measurements by | 19 |
| Clay, character and distribution of | 17 |
| Climate, description of | 17–25 |
| Coe, J. H., wells of | 13 |
| Cones, cinder, occurrence of | 8 |
| Cones, detrital, occurrence and description of | 7 |
| Cooper, ——, on cement rock | 17 |
| Coso district, volcanic features of | 7 |
| Coso Mountains, altitude of | 5 |
| Crooked Creek, rocks on | 8 |
| view of | 16 |
| Darton, N. H., work in charge of | 5 |
| Dall, W. H., fossils determined by | 7 |
| Diller, J. S., on structure of Owens Valley | 9, 10 |
| Dodge Brothers, well of | 13 |
| Drainage, description of | 6, 25 |
| Duryee, Edward, on cement rock | 17 |
| Earthquake, effects of | 12, 16 |
| Ephydra, occurrence of | 21 |
| Evaporation, irrigation and, relations of | 23–25 |
| rate of | 19–20 |
| Fairbanks, H. F., on Tertiary rocks | 7 |
| Fish Spring Volcano, description of | 8 |
| Flowing wells, distribution of | 13–14 |
| Geography, description of | 5–6 |
| Geologic history, outline of | 10–12 |
| Geology, description of | 6–12 |
| Geysers, mud, description of | 9 |
| Gilbert, G. K., on structure of Owens Valley | 9, 10 |
| Goodyear, W. A., on Owens Lake | 21 |
| Granite bowlders, view of | 10 |
| Haway Meadows, well at, rocks in | 7, 10 |
| High Sierra, views of | 10, 24 |
| Historical geology, outline of | 10–12 |
| Holloway, J. F., ranch of, cement rock near | 17 |
| Hot Creek, origin of | 8 |
| Hot Springs, description of | 8 |
| Independence, altitude at | 5 |
| lavas near | 8 |
| temperature at | 20 |
| Inyo Development Company, soda plant of | 21 |
| wells of | 13 |
| Irrigation, evaporation and, relations of | 23–25 |
| Keeler, altitude at | 5 |
| rainfall at | 18 |
| soda-recovery plant at | 21 |
| well at | 13, 14 |
| well at, record of | 7 |
| Lakes, variations in, evidence from | 20–25 |
| *See also* Owens Lake, Mono Lake. | |
| Lava flows, occurrence and description of | 7–8 |
| Le Conte, Joseph, on Sierra Nevada | 10–11 |
| Limestone, character and distribution of | 17 |
| Lindgren, W., on movements in Sierra Nevada | 11–12 |
| on structure of Owens Valley | 9, 12 |
| Little Lake, elevation of | 10 |
| rocks at | 10 |
| Loew, Oscar, analysis by | 21 |
| Lone Pine, altitude at | 5 |
| wells at | 13 |
| Long Valley, reservoir site in | 15–16 |
| Long Valley district, volcanic features of | 8 |
| Longley, A. W., well of | 14 |
| Lyell, Mount, altitude of | 5 |
| glacier on | 24 |
| view of | 24 |
| McLean, J. J., temperature records by | 20 |
| Mammoth Mountain, peneplain at | 10 |
| view of | 24 |
| Map of Owens Valley | 6 |
| Marble, occurrence of | 10, 17 |
| Materials, structural, description of | 16–17 |
| Mono Lake, drainage to | 6, 24 |
| chemical character of | 23 |
| increase of | 23, 24–25 |
| physical character of | 23 |
| water of, analysis of | 23 |
| Mud geysers, description of | 9 |
| Odonta sp., occurrence of | 7 |
| Olanche, well at | 13 |
| Owens Lake, cement rock near | 17 |
| chemical character of | 21–22 |
| drainage to | 6 |
| evaporation at | 19, 23–25 |
| physical character of | 20–21 |




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| | Page. |
|---|---|
| Owens Lake, rocks near | 6 |
| shrinkage of, cause of | 23-25 |
| water of, analyses of | 21, 22 |
| Owens River, description of | 6 |
| rocks on | 8 |
| tributaries of | 6 |
| Owens Valley, development of | 10-12 |
| location of | 5 |
| origin of | 10 |
| structure of | 9-10, 12 |
| vicinity of, map of | 6 |
| view of | 8, 12 |
| Panum Crater, description of | 8 |
| view of | 16 |
| Peneplain, character of | 10 |
| Phillips, Professor, analysis by | 21 |
| Power plants, development of | 15 |
| Preble, E. C., on cement rock | 17 |
| Precipitation, amount of | 6, 17-19 |
| Pumping plants, character and distribution of | 14-15 |
| Quaternary sediments, character and distribution of | 7 |
| Quaternary time, movements in | 11-12 |
| Rainfall, amount of | 6, 17-19 |
| Reservoir, possible damage to, by earthquakes | 16, 25 |
| site of, description of | 15-16 |
| Ritter, Mount, altitude of | 5 |
| Rock Creek, rocks on | 8 |
| Rocks, descriptions of | 6-7 |
| Roeper, J. C., well of | 13 |
| Rush Creek, description of | 6 |
| Russell, I. C., on Mono Lake region | 8, 10 |
| on Owens Valley region | 9 |
| Sierra Nevada, view of | 8 |
| Soda, extraction of | 21 |
| Spear, R. C., well of | 13 |
| Stone, building, character and distribution of | 16 |
| Stone, C. H., analysis by | 22 |
| Stratigraphy, description of | 6-7 |
| Structural materials, description of | 16-17 |
| Structure, description of | 9-10, 25 |
| Swamps, development of | 15 |
| Taylor, R. J., evaporation records by | 20 |
| Temperature, records of | 20 |
| Tertiary rocks, character and distribution of | 6-7 |
| Topography, description of | 5 |
| Tuff, cement-making qualities of | 16-17 |
| Turner, H. W., on Sierra Nevada geology | 11 |
| Underground waters. *See* Waters, underground. | |
| Uplift, occurrence of | 10-11 |
| Volcanic ash, occurrence of | 7 |
| use of | 16, 17 |
| Volcanic features, description of | 7-9 |
| Walcott, C. D., on Inyo Range | 11 |
| on Tertiary rocks | 7 |
| on structure of White Mountains | 9 |
| Water table, depth to | 15 |
| Waters, underground, conditions of | 12-13 |
| development of | 13-14, 25 |
| utilizations of | 14-15 |
| Waucobi embayment, rocks in | 6-7 |
| Wells, descriptions of | 13-14 |
| Wells, flowing, area of | 14 |
| White Mountains, altitude of | 5 |
| structure of | 9 |
| view of | 10 |
| Whitney, J. D., on Owens Valley earthquake | 12 |
| on structure of Owens Valley | 9 |
| Whitney, Mount, altitude of | 5 |
| table-lands near | 11 |
| view of | 8 |
| Williamson, Mount, altitude of | 5 |
| Wrinkle, N., analysis by | 22 |
| on soda-recovery plant | 21 |
| well of | 13 |


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